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JULY 1990 THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

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SPEA 7/90

Circle No. 1

NEWSLOG

MAY 8: The Federal Communications Commission awarded Millicom Inc., New York City, a two-year license for an experimental cellular telephone network that will expand the number of callers who can use it simultaneously. Millicom plans systems for 25 000 subscribers in Houston, Texas, and 20 000 in Orlando, Fla.

MAY 14: After announcing a 97 percent earnings fall for its first quarter, Philips NV, Eindhoven, the Netherlands, said chairman Cornelis J. van der Klugt would resign July 1 and be replaced by consumer-electronics director Jan D. Timmer. Analysts said Timmer would have to speed up Philips' restructuring to plug losses, notably in computers and ICs.

MAY 15: The Silicon Valley Group, San Jose, Calif., said it would acquire Perkin-Elmer Corp.'s optical lithography division, keeping in U.S. hands the means of producing future IC generations. IBM Corp. helped orchestrate the deal.

MAY 20: Scientists at the Goddard Space Flight Center, Greenbelt, Md., said the first images from the Hubble Space Telescope were two to three times better than expected. The 1- and 30-second photos showed the NG3532 star cluster.

MAY 22: Lepton Inc., a Bell Laboratories spinoff in Murray Hill, N.J., introduced its EBIS-4 machine, which uses direct-write electron-beam lithography to create chip features as small as an eighth of a micrometer.

MAY 23: The U.S. Senate Commerce Committee approved a bill that would allow the seven regional Bell operating companies to design, make, and sell home telephones and other equipment. The bill demonstrates Congressional interest in assuming oversight of the industry from Federal District Judge Harold H. Greene, whose 1984 court order barred the Bell companies from such manufacturing.

MAY 25: A study released by the Oak Ridge National Laboratory, a U.S. Energy Department research center in Oak Ridge, Tenn., said a Japanese supercomputer has for the first time taken the title of the world's fastest single-processor computer. The S-820/80 of Hitachi Ltd., Tokyo, reached 107 million floating-point operations a second (megaflops), significantly exceeding the 90-megaflops Y/MP supercomputer of Cray Research Inc., Minneapolis, Minn., when the speed of a single processor was measured.

MAY 29: Four years after completion and 14 years after construction began, New Hampshire's Seabrook nuclear power plant began supplying electricity to customers, operating at 15 percent capacity and serving 65 000 homes.

MAY 30: Honeywell Inc., Minneapolis, Minn., and Northwest Airlines Corp., St. Paul, Minn., agreed to work with the USSR to develop a new satellite navigation system for aircraft that will for the first time link the Soviet Glonass and the U.S. Navstar systems.

MAY 30: A Pennsylvania state appellate court ruled that services that identify callers' telephone numbers are an illegal invasion of privacy. The court said they violate the state's wiretap law—even when phone companies let customers block release of their numbers.

MAY 31: In what the Justice Department said was the first criminal case charging a violation of the 1982 consent decree that broke up the AT&T Co., a Federal grand jury indicted the Nynex Corp., based in New York City. The jury said Nynex sold computer data-processing services over telephone lines to MCI Communications Corp., Washington, D.C., after its 1986 acquisition of a software company that had leased a computer and software to MCI.

MAY 31: After years of delay, Japanese electronics companies received their Government's approval to sell digital audio tape (DAT) decks that can make virtually perfect copies of compact discs. U.S. song writers and record manufacturers concerned about copyright oppose DAT, but a bill pending in Congress would limit the copies DAT recorders could make.

JUNE 1: JVC (Victor Company of Japan Ltd.), Tokyo, said it will form a joint venture with Philips NV, the Netherlands, to produce VHS videocassette recorders in Malaysia. The new venture is due to start production in early 1991.

JUNE 5: The U.S. Commerce Department told U S West Inc., Englewood, Colo., that the Government opposed a project to build an optical-fiber cable communications system across the USSR, linking Japan and Europe. The department expressed concern that building the $500 million system could threaten the national security and said it opposed any country's release of such technology to the USSR.

JUNE 6: A Federal appeals court reversed two decisions the Federal Communications Commission (FCC) had made in 1986: permitting local telephone companies to provide computer information services over phone lines without setting up separate subsidiaries and allowing these operations to be free of oversight by state regulators.

JUNE 6: The Japanese Government chose U.S. technology for its next-generation digital cellular telephones. Motorola Inc., Schaumburg, Ill., outperformed seven Japanese and European companies in a performance test of the Ministry of Posts and Telecommunications. The decision will help U.S. cellular-equipment companies compete in Japan, where their equipment is now incompatible.

JUNE 8: Hitachi Ltd., Tokyo, claimed it was the first to have developed a working memory cell for a 64M-bit chip. The cell is 1.28 micrometers square, and the chip, 20.28 by 9.74 millimeters square. But the company later said it may take 18–24 months to develop a fully functional prototype chip.

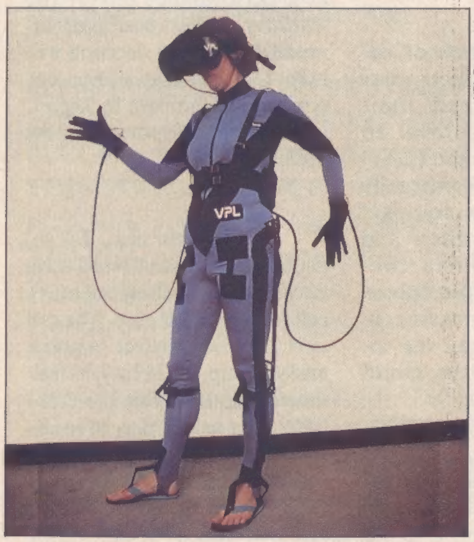
JUNE 8: A U.S. group of companies, universities, research laboratories and Government agencies said it would develop an advanced computer network in which data would be transmitted at speeds 700 times faster than possible now. The network will start up with $15 million from the National Science Foundation and the Defense Advanced Research Projects Agency plus over $100 million from private companies.

Preview:

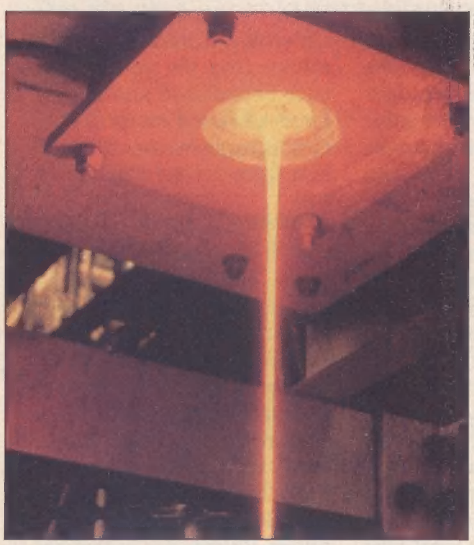
JULY 1: Final regulations are to be published for the 17-nation Coordinating Committee on Multilateral Export Controls' (Cocom's) agreement reducing export curbs on high-technology products to Warsaw Pact nations. The accord, reached on June 7 in Paris, eases a 41-year embargo on sales of mainframe computers, telephone exchanges, and sophisticated telecommunications equipment to the Eastern bloc.

Coordinator: Sally Cahur

IEEE
SPECTRUM
VOLUME 27 NUMBER 7 JULY 1990



40 "Goggle-and-glove" presents a new twist in human-computer interactions



18 Nuclear waste and molten glass flow into a cask in Cap La Hague, France

Cover: Only 2 micrometers thick, this polysilicon variable-capacitance motor has a rotor 60 µm in diameter and a 2-µm-wide air gap between rotor and stator. One of the world's first functional micromoters, it was fabricated at the University of California at Berkeley in spring 1988. The eight-pronged rotor is spun around a bearing by elecrostatic forces generated by sequentially applying voltages to the encircling stator poles. The colors in the optical micrograph are due to interference effects in the thin films coating of the silicon substrate. See p. 31.
Photo: Yu-Chong Tai, Richard S. Muller, University of California at Berkeley

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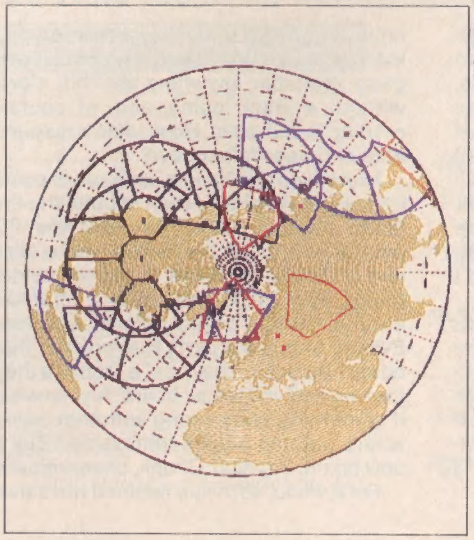
The Audit Bureau


Jim Pickerell

In Washington, D.C., Robert S. Cooper ponders what to launch next **44**


U.S. Air Force

Projected over-the-horizon radar coverage by three countries **36**

The electronic hobbyist

Electronics used to be fun. Maybe it still is, but sometimes I have doubts. When I was a youngster, I discovered a book in the library entitled *Boy's First Book of Radio*. It was an old book even then, but now it would look archaic. Each chapter gave instructions about how to build an ever more complicated radio, starting with a crystal set in the first chapter and ending with a superhet in the last. I was enthralled with the adventure of it all and eagerly started to build my very own crystal set.

My first great discovery was that crystal sets did not work. I built them both from scratch and from kits, but never got any of them to bring in a single station. That piece of rock on the end of the cat's whisker was a bad idea—solid-state electronics was not ready for the big time. However, undiscouraged, I found that miracles could be wrested from vacuum tubes. All you had to do was to wire them up in endlessly possible configurations, and you could pull voices out of the ether. This was good stuff—electrical engineering was for me.

Transistors came along, but no matter, they were just like little tubes, and by wiring them together with resistors and capacitors, you could do neat things. Now I concentrated on kits. See my great hi-fi system? I built it myself, saved a bundle, and if anything ever goes wrong with it, I can fix it. See my TV set? Yep; built it myself. A beauty if I do say so. People marveled at how clever and dexterous I was. Not that it was very hard, following instructions like: "Connect a 3-inch length of hookup wire between connector KK (S-3) and QQ (S-2) of the IF-audio circuit board." It gave me a feeling of accomplishment and pride in the finished product. I have some of those kits—still in working order, too. I keep waiting for them to break so I can fix them myself.

But then something changed. Integrated circuits came along, and all those transistors and resistors got scrunched into little chips. Worse yet, all the wires were in there, too, with the external wires connecting the chips together etched onto a printed-circuit board. Nobody cut that little wire and wrapped it around the solder lug anymore. They still sold kits, but now all you did was stuff the parts onto the board and solder the connections. It still felt good, but I began to wonder why I was doing this.

Just about the time most of the fun had gone, personal computers came along. Altair got all the experimenters excited. The microprocessor was a fantastic engine, but it was only a single chip. Lots of other stuff had to be designed and wired, and hardly any software existed. The field was wide open. I was more proud of my home-designed computer than of any of those hi-fi kits. This was more like it!

Alas, that lasted only briefly. Now my third-generation home computer is humming quietly to itself while I write these words on one of those ubiquitous word processors. There is something wrong with the computer, but I haven't the chance of the proverbial snowball of fixing it myself. I don't even know what is inside the case anymore. The very large-scale IC chips confined there have only cryptic markings on them. There is no circuit diagram available anywhere for this clone without a brand name, and, of course, nothing is socketed. How could a respectable engineer fall so low?

I never see ads for kits anymore. It costs more to package a kit than to build the finished product. When you see the PC boards go through the factory, you realize why it makes no sense to wire or solder things yourself. Chunk, chunk, chunk—another perfect board rolls off the line. Ever try to buy the parts that go onto that board? Forget it. They cost a lot more than the finished and tested board. And so what if something goes wrong with that board where nothing seems removable? Buy a new board. Big deal. Chunk, chunk, chunk.

For a while, software seemed the salvation of the hobbyist. The hardware industry had standardized everything anyway. Even if you wanted to design your own system, it made no sense. Only one or two designs were supported the world over. But in software there was infinite variety. Everyone could do his own thing. I wrote operating systems, compilers, editors, neat programs. It was fun, and it was educational. Good for me.

Before I realized its transience, the golden age of personal computers ended. One day I looked around for some program to write, but there was nothing left. Anything I could think of had already been packaged as a commercial program that worked far better than one I could ever write. Worse yet, there was always a free program that was better than anything I could accomplish. There was no excuse for building either hardware or software. You couldn't save money, and you couldn't make anything different.

The magazines that used to have circuit diagrams and software code just turned to reviews of commercial products. Last week, I went to a computer flea market that has been a regular source of experimenter junk for over a decade. Two discouraged men passed by. One shook his head sadly and said, "It's all gone commercial." I raised my eyes and surveyed the field, and I realized that I was looking at five hundred stands and booths all selling the same two dozen commercial products. What was I doing there?

Now what? How about *Boy's and Girl's First Book of VLSI Design*? The kit comes with a bunch of CAD software disks and a certificate to send your finished design in to the VLSI foundry shuttle for fabrication. Or what about *Build Your Own Molecular Beam Epitaxy Machine in Your Spare Time*? And with all the research on finer linewidths using X-ray lithography, maybe there will be a market for home synchrotrons. Be the first to get your neighbors together and run the loop around your block.

I hear that freshman enrollment in electrical engineering has been dropping steadily since those halcyon early days of personal computing. I'm looking at my non-distinctive, keep-your-hands-off clone, and I'm wondering—do you think there is any connection?

—Robert W. Lucky

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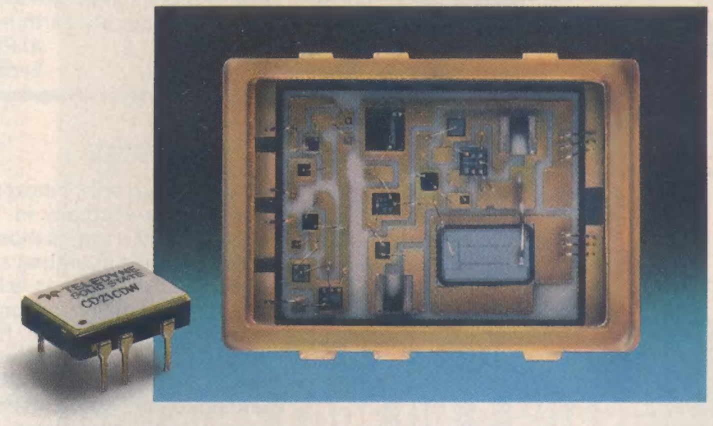


ACTUAL SIZE CERAMIC PACKAGE

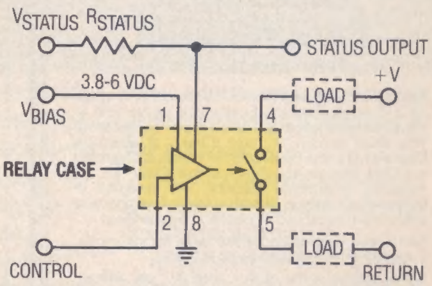
PART # CD21CDW

Review the electrical characteristics and call us for immediate application assistance.*

ELECTRICAL CHARACTERISTICS (–55°C to +105°C unless otherwise noted)	Min	Max	Units	
Bias Voltage (V_{BIAS})	3.8	6.0	V_{DC}	See Note 1
Bias Current (I_{BIAS})		15.0	mA	$V_{BIAS} = 5V_{DC}$
Control Voltage (V_{IN})	0	18.0	V_{DC}	
Control Current (I_{IN})		250	µA	$V_{IN} = 5V_{DC}$
Turn-Off Voltage $V_{IN(OFF)}$	3.2		V_{DC}	
Turn-On Voltage $V_{IN(ON)}$		0.3	V_{DC}	
Continuous Load Current		1.2	A	–55°C to +25°C
I_{LOAD} @ 60VDC		0.7	A	+85°C
Output Trip Current (I_{TRIP})	2.4 (Typ.)		A	+25°C, 100ms
On-Resistance (R_{ON})		0.65	Ohms	
Turn-On Time (T_{ON})		1.5	ms	
Turn-Off Time (T_{OFF})		0.25	ms	
Status Voltage (V_{STATUS})	1	18	V_{DC}	
Status Current (I_{STATUS})		2	mA	$V_{SAT} \leq 0.3V_{DC}$ See Note 2

Notes:
1. Series resistor is required for bias voltages above $6V_{DC}$. $RS = (V_{BIAS} - 6V_{DC})/15$ mA
2. A pull up resistor is required for the status output. $R_{STATUS} = (V_{STATUS} - 0.3)/I_{STATUS}$
3. Output will drive loads connected to either terminal (sink or source).
4. Status circuit is a built-in test feature checking the input circuitry of the relay. Status output is low (on) when the input is on.

All power FET relays may drive loads connected to either positive or negative referenced power supply lines (source or sink modes).



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Circle No. 13

FORUM

Seeking shelter from the storm

The very interesting article on "Bracing for the geomagnetic storms" [March, p. 27] raises three points.

First, geomagnetically induced current in overhead lines could bypass the main transformer windings if the neutral points at each end of the line were bonded to an extra "earth" conductor that was also bonded to each tower. This conductor would be a fairly simple modification to the installed system.

Second, the solar panels of communication satellites could be protected from the solar wind by a system of rare-earth permanent magnets that would deflect the charged particles to harmless parts of the structure. The third point would be to use the solar wind to boost the satellite power supply in a magnetohydrodynamic assembly also using rare-earth magnets.

Alan Armstrong
Eynsham, England

Tracking TCAS

TCASII equipment ["Innovations: Antenna ups bearing accuracy in TCASII," April, p. 11] only interrogates those aircraft within range. When operating at dense-traffic airports, interrogations will be limited to just 18 aircraft per second. Because it operates on the same frequencies as those of the air-traffic control (ATC) radar beacon frequencies, not all aircraft can be equipped, and range is limited at airport areas. Also, no threat-resolving advisories will be given, only traffic advisories; otherwise there would be too much interference. Without having all aircraft able to communicate with each other, there can be no assurance of a safe separation. In a spatial conflict, an unequipped threatening aircraft may make a maneuver that cancels a correcting one being made by the ship with the onboard collision-avoidance system (TCAS). It is the range and range rate, used to compute time to the point of closest approach, which determine the threat of collision.

"Innovations" describes a bearing-measuring capability. Yet, as described, that bearing capability plays no part in determining what escape maneuver to make. If the criterion for a safe separation lies in achieving an adequate altitude difference, then it makes no difference what the intruder's bearing is.

Bearing information is needed by TCAS because in dense-traffic areas TCAS will not provide pilots with threat-resolving advisories, just traffic advisories. It will then be incumbent upon flight crews to try to locate intruders visually. Knowing the intruder's bearing, as well as altitude, will help. If, however, the intruder is outside the visual range of the pilots or approaching from the direction of the sun, locating that bearing will be nearly impossible. Should the weather not be clear, or the intruder approaching from a lower altitude over a well-lit city at night, picking the bearing up in time to make a corrective maneuver will be "iffy" at best. Should an unequipped intruder make a wrong move, then a collision could ensue in spite of the presence of TCAS.

Because of the need to equip all aircraft, and because of the need for timely threat-resolving advisories under all conditions, the data link of TCAS needs to be changed, so that TCAS cannot interfere with ATC communications and ATC communications cannot interfere with TCAS. There is also a need for a range able to provide pilots with an adequate warning time and optimized threat-evading resolution advisory. Until such changes are made, TCAS will be worse than nothing in dense-traffic areas. Pilots, believing that they are protected, will not be doing much traffic surveillance themselves, and the equipment's data link will not be reliable.

E. R. Gunny
Los Angeles, Calif.

Wescon

I was shocked to read that the American Electronics Association (AEA) sponsors Wescon, the Western Electronics Show and Convention [May, p. 50]. AEA's 50 percent interest in Wescon was purchased by IEEE in 1973. Since then, Wescon has been owned and operated by the San Francisco and Los Angeles chapters of the Electronics Representatives Association (to whom the IEEE sold a 30 percent interest).

Charles A. Eldon
Los Altos, Calif.

We regret that, because of a copy-editing error, the statement that AEA originated Wescon was changed to AEA sponsors Wescon. —Ed.

Corrections

On p. 36 of the May issue, two photomicrographs of magnetic recording media should have been credited to Drexler Technology Corp., Mountain View, Calif.

On p. 14P of the June issue, the dates for the 40th Annual Broadcast Symposium should have been Sept. 6–7.

On p. 59 of the June issue, the logarithmic-scale marks of the curve "Activity in electrotechnology research . . ." should be 1, 10, 100, 1000, 10 000, and 100 000.—*Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues.

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onference on Power Elec- **Speed Drives** (IA et al.); 1 of Electrical Engineers, oping, IEE Conference ace, London WC2R OBL, 1871, ext. 218.

Conference on Vacuum ; July 22-25; Doubletree alif.; Reedy Langevin, 655 15th St., Suite 300, 005; 202-347-5900.

ings (LEO)—**Broadband** **:s: Devices and Systems;** **ultiple Access Networks;** **d Optoelectronics;** July heraton, Monterey, Calif.; 45 Hoes Lane, Box 1331, 55; 201-562-3896.

Magnetic Recording Conference (MAG); July 23-26; University of California-San Diego, La Jolla, Calif.; Kanu G. Ashar, IBM Corp., PO6/025, 5600 Cottle Rd., San Jose, Calif. 95193; 408-256-3541.

Conference of the Society of Instrument and Control Engineers of Japan (IE); July 24-26; Tokyo, Japan; Hiro Yamasaki, SICE President, 1-35-28-303 Hongo, Tokyo 113, Japan; (81+3) 814 4121.

AUGUST

Summer Topical Meetings—New Semiconductor Laser Devices and Applications (LEO); Aug. 1-3; Monterey Sheraton, Monterey, Calif.; G. McBride, LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855; 221-562-3896.

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MEETINGS □ CONFERENCES AND CONVENTIONS

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For additional information on hotels, conference centers, and travel services, see the Reader Service Card.

JULY

Third International Conference on Industrial and Engineering Applications of AI and Expert Systems (COMP); July 15-18; Mills House Hotel, Charleston, S.C.; Moonis Ali, University of Tennessee, Space Institute, M/S-15, Tullahoma, Tenn. 37388; 615-455-0631.

Power Engineering Society Summer Meeting (PE et al.); July 15-19; Marriott and Radisson Hotels, Minneapolis, Minn.; S. L. Larsen, Northern States Power Co., 414 Nicollet Mall, 8th floor, Minneapolis, Minn. 55401; 612-330-6149.

Nonlinear Optics: Materials, Phenomena and Devices (IEEE/LEO); July 16-20; Stouffer Waiohai Beach, Kauai, Hawaii; Glenda McBride, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855; 201-562-3896.

Fourth International Conference on Power Electronics and Variable-Speed Drives (IA et al.); July 17-20; Institution of Electrical Engineers, London; Jane Chopping, IEE Conference Department, Savoy Place, London WC2R OBL, England; (44+1) 240 1871, ext. 218.

Third International Conference on Vacuum Microelectronics (ED); July 22-25; Doubletree Hotel, Monterey, Calif.; Reedy Langevin, Courtesy Associates, 655 15th St., Suite 300, Washington, D.C. 20005; 202-347-5900.

Summer Topical Meetings (LEO)—**Broadband Analog Optoelectronics: Devices and Systems;** July 23-25; **Optical Multiple Access Networks;** July 25-27; **Integrated Optoelectronics;** July 30-Aug. 1; Monterey Sheraton, Monterey, Calif.; G. McBride, LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855; 201-562-3896.

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Rust to Riches: The Coming of the Second Industrial Revolution. *Rutledge, John, and Allen, Deborah,* Harper & Row, New York, 1989, 207 pp., $19.95.

According to the authors of this book, "America's business managers have been radically altering the way they run their companies, quietly laying the foundation for [redacted] second revolution. . . .This Renaissance of American manufacturing will serve as the driving force that will bring a decade of prosperity without inflation and create tremendous investment opportunity for those who understand the process driving the economy."

Most U.S. citizens are hoping that the authors are correct.

Rust to Riches is about change in the U.S. economy, the foundation of which has already been laid. Its fundamental premise is that during the decades preceding the mid-1980s, the U.S. economy [redacted] great investment in everything except manufacturing productivity. Because of inflation, rising tax rates, and expanding tax shelters, investment focused on hotels, office buildings, and shopping centers, causing what the authors call [redacted] "massive shortage of productive, usable industrial capital." But by the mid-1980s, inflation had abated and the tax code was revamped, prompting a reevaluation of business investment.

The authors also blame the massive, and much maligned, group of "Baby Boomers" for the lack of an adequate pool of savings and subsequent retarded investment spending by business. This group, born between 1945 and 1964, have been spenders, not savers. But traditionally, the authors say, U.S. citizens do not become savers until their mid-forties; research shows that people spend more than they earn until their late-thirties, break even for [redacted] few years, and then in their mid-forties begin accumulating savings for retirement. As more and more Boomers move into this age of savings, more wealth will become available for investment.

Thus, the savings rate in the United States, even with a swelling number of retired people, should rise during the next 30 years. Rutledge and Allen [redacted] convinced that "this turnaround will begin as a trickle of savings, but will become a flood by the year 2000, when the middle of the Baby Boom will be forty-five years old, and the oldest will be in their mid-fifties. Private savings generated by the Boomers, plus the huge surplus their tax payments will create in the Social Security trust fund while the Boomers work, will add trillions of dollars to domestic financial markets."

However, the authors fail to note that the savings rate of those Boomers currently in the 24–34 age group is lower than it was for the same age bracket 20 years ago. Obviously, behavior has changed. It should also be mentioned that Baby Boomers will finance their children through a longer education "career" because more of their offspring attend college and graduate school than did the Boomers. Compared to *their* parents, Baby Boomers are also spending more of their salaries in paying off debt: for houses, two cars, and so on. While many of their parents saved diligently because their formative influences included the Great Depression and World War II, Baby Boomers today have available to them more consumer goods than ever before, and they have learned to seek instant gratification.

To be fair to Rutledge and Allen, however, one must concede that Boomers [redacted] so numerous that their savings will increase and probably be invested much more productively than before, since investment dollars go much farther today. Moreover, the book is not concerned with what will happen when the Baby Boom generation reaches retirement age. The authors limit their outlook to the next three decades.

Conventional wisdom has it that the great trade deficit is the major problem with the U.S. economy. Rutledge and Allen emphatically disagree. They point out that foreign investment in the United States has been so strong mainly because higher rates of return are earned in the United States than in most foreign markets. The United States has been, and will continue to be, a good investment, they say. For example, in the 1980s, it created 15 million more jobs than did Europe, which has [redacted] larger population.

The facts that the country is borrowing from abroad and that Europeans and Japanese are investing vigorously in the U.S. economy do not indicate that the United States is in trouble—far from it, in the authors' view. They note that "in 1888 the United States was the world's largest debtor nation." But by investing in manufacturing capacity—that is, by borrowing and wisely investing—the United States in the 1880s, like Japan in the 1950s and 1960s and Korea in the 1970s, reaped major surpluses in due time. (In 1985, Korea [redacted] the world's fourth-largest debtor nation.)

As the authors put it, "the purpose of international borrowing is to increase our capital stock so that output, employment, and productivity can expand." The recent growth in the U.S. balance of payments deficit is due not to runaway consumer spending, but to increased imports of capital equipment and industrial supplies and materials, they argue. These items account for over 50 percent of the growth in the balance of payments since 1980.

Overall, the book is persuasive and provocative, but there are annoying aspects. The chapter on warding off corporate takeovers, titled "How to Keep T. Boone Pickens Out of Your Company," is an excellent example of the book's strengths and weaknesses. Its introduction reads like a lighthearted start of a training session, which seems out of place in [redacted] serious book. Nonetheless, much of the advice is sensible, relevant, and to the point. At times, though, the reader wishes some of the authors' conclusions were supported by hard facts.

For example, they write that "private companies are run better than public companies. Not always but usually." Yet, they admit that General Electric Co. is one of the best-managed organizations. No mention is made of the fact that most new businesses (which are mostly private companies) do not last five years.

Another problem is that the authors concentrate on businesses with heavy capital equipment. What about service companies or hospitals and medical organizations? These major sectors of the U.S. economgy [redacted] ignored. Service firms tend to have very little heavy capital investment, while the medical companies [redacted] generally capital-intensive (but are not, strictly speaking, business entities).

The authors often use analogies to demonstrate their points. Some are simple and elegant: they say buildings have vintages just like wines, for example. But too many of these analogies are over-simplified and too long, like one, pages long, that concerns capital formation and Lincoln Logs, the U.S. children's toy.

Rutledge and Allen are quite optimistic about the next few decades and even predict that by 1995 the U.S. manufacturing economy will be booming. U.S. products will be selling well not only domestically but globally. They offer convincing arguments, and I hope they are right.

The United States may be on the verge of winning back [redacted] great deal of the world's markets. But even if it can quickly improve prices and quality, one wonders how long it will take to win back credibility for its products. That may take a lot longer.

—*Ronald G. Greenwood*

Ronald G. Greenwood is the F. James McDonald Distinguished Professor of Industrial Management at GMI Engineering [redacted] Management Institute in Flint, Mich. He is the author, with Charles D. Wredge, of a book on Frederick Taylor, the father of scientific management, to be published next year.

Coordinator: Glenn Zorpette

RECENT BOOKS

Systèmes Microprogrammés: Une Introduction au Magiciel. *Mange, Daniel,* Presses Polytechniques Romandes, Lausanne, Switzerland, 1990, 400 pp., SFr. 64.

Digital Satellite Communications–2nd Edition. *Ha, Tri T.,* McGraw-Hill, New York, 1990, 641 pp., $59.50.

RS/1. BBN Software Products Corp. IBM PC and compatibles; 512K RAM and 20-Mbyte hard disk required, graphics card and mathematics coprocessor strongly recommended. $895.

In these days of global markets that demand ever-higher quality and reliability, computer-integrated manufacturing (CIM) is arriving in factories not only as massive changeovers but also piece by piece. Bar coding and automated part inspection, using machine vision, for example, may be added to existing systems as a first step that could lead into CIM.

BBN Software Products Corp.'s RS/1, combined with QCA (its associated quality-control statistical package), offers a suitable platform for slow and steady integration of these kinds of CIM tools. I strongly recommend this system, with the stipulation that a trained manufacturing systems engineer must write the code and integrate the final program into the company's existing system.

BBN calls RS/1 a "comprehensive data management, data analysis, and graphics tool for scientific, engineering, and manufacturing professionals." If anything, the word comprehensive is an understatement: RS/1 is an operating system, a programming language, a graphics package, and a statistical analyzer all in one. It provides an easy means of constructing engineering applications that incorporate multiple tasks: interfacing data acquisition with voice recognition, perhaps. Version 4.2 also has the option of pull-down menus.

By itself, RS/1 provided all the capabilities of an in-house system we had recently designed to create, manipulate, and analyze engineering and manufacturing data files for use in factory operations. Manipulating, storing, and transporting files, using interfaces to pre-existing spreadsheets and data bases, were all easily accomplished from within RS/1.

In contrast, our in-house system had required us to build into it commercial quality-analysis, graphic presentation, and Pascal programming packages. Some of its presentations had to be done from output files produced by the quality-assurance package, others from fixed-format ASCII files. RS/1, on the other hand, met all of these needs in an integrated fashion. It handled ASCII files well, although empty fields sometimes caused problems.

RS/1's graphics capabilities extend to three dimensions, where up to 10 separate objects—including files and graphs—can be printed or plotted onto a page. Online help is provided for all functions.

RS/1 comes on all of 18 diskettes (QCA adds another 3 diskettes), plus nine volumes of user manuals. As with many such packages, the user must identify the system configuration to the program. Installation was easy, although time consuming.

BBN offers two other noteworthy products: RS/Explore, for R&D, and RS/Discover, for experimental design. So far, they are available only on workstations. But they, too, are likely to find their place as companies turn to desktop computers in the drive to make factories more efficient. *Contact: BBN Software Products Corp., 10 Fawcett St., Cambridge, Mass. 02238; 617-873-5000.* —*Richard Lee*

Richard Lee (M) is a project engineer at Philips Components, Slatersville, R.I., a division of North American Philips Corp. His research interests include industrial laser applications and optical-fiber communications. He tested RS/1 on an IBM PC AT with a 300-Mbyte hard disk, a mathematics coprocessor, a graphics processor, a frame grabber, and an in-house data acquisition board connected to remote sensors through optical fibers.

Coordinator: Erin E. Murphy

IEEE Spectrum selects software for review on the basis of potential interest to the engineering community. A review does not imply any form of endorsement or recommendation. The opinions expressed by reviewers are their own.

CALENDAR

(Continued from p. 11)

Second IEEE Power Electronics Society Workshop on Computers in Power Electronics (PEL); Aug. 6-7; Bucknell University, Lewisburg, Pa.; Thomas Sloane, Department of Electrical Engineering, Bucknell University, Lewisburg, Pa. 17837; 717-524-1269.

International Conference on Systems Engineering (AES); Aug. 9-11; Vista International Hotel, Pittsburgh; B. A. Shenoi, Department of Electrical Engineering, Wright State University, Dayton, Ohio 45435; 513-873-3527.

33rd Midwest Symposium on Circuits and Systems (ASSP et al.); Aug. 12-14; Calgary Convention Centre, Canada; R.H. Johnston, Department of Electrical Engineering, University of Calgary, 2500 University Dr., N.W., Calgary, Alta. T2N 1N4, Canada; 403-220-5003.

16th International Conference on Very Large Databases (COMP); Aug. 13-16; Sheraton Brisbane, Brisbane, Australia; Richie Research Laboratories, University of Queensland, St. Lucia, Q4067, Australia; (61+7) 377 2911.

Hot Chips Two (COMP); Aug. 20-21; Mayer's Theater, Santa Clara University, California; Hasan Alkatib, Department of Electrical Engineering and Computer Science, Santa Clara University, Santa Clara, Calif. 95053; 408-554-4485.

15th International Conference on Electric Contacts with 36th Holm Conference on Electrical Contacts (CHMT); Aug. 20-24; Le Grande Hotel, Montreal; Georgina Crane, IEEE, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855; 201-562-3863.

International Symposium on Electromagnetic Compatibility (EMC); Aug. 21-23; Washington Hilton Hotel, Washington, D.C.; R.J. Mayer, Commerce Department, National Telecommunications and Information Administration, 14th and Constitution Ave., N.W., Rm. 4096, Washington, D.C. 20230; 202-377-1138.

International Conference on Solid State Devices and Materials (ED); Aug. 22-24; Hotel Sendai Plaza, Sendai, Japan; Kazuo Tsubouchi, Research Institute of Electrical Communications, Tohoku University, Sendai 980, Japan; (81+022) 227 6200, ext. 2836.

The East Coast Conference on Biomechanics (EMB); Aug. 26-28; New York College of Osteopathic Medicine, Old Westbury, N.Y.; H.S. Ranu, Department of Biomechanics, New York College of Osteopathic Medicine, New York Institute of Technology, Old Westbury, N.Y. 11568; 516-626-6926.

International Symposium on Signal Processing and Its Applications (Queensland); Aug. 27-30; Conrad International Hotel, Broadbeach, Australia; B. Boashash, Crisssp, Department of Electrical Engineering, University of Queensland, St. Lucia, Australia 4067; (61+7) 377 3237.

Seventh International Conference on Electromagnetic Compatibility (UKRI Section); Aug. 28-31; University of York, England; Louise Bousfield, IEE Conference Services, Savoy Place, London WC2R OBL, England; (44+1) 240 1871.

SEPTEMBER

International Telecommunications Conference-ITS '90 (COM); Sept. 3-6; Rio de Janeiro, Brazil; Jose Roberto Boisson de Marca, Cetuc-Puc/Rio, Rua Marques de S. Vincente 225, 22453 Rio de Janeiro, RJ, Brazil; (55+21) 529 9450.

Close-Range Photogrammetry Meets Machine Vision (COMP); Sept. 3-7; Zurich; Horst Beyer, Institute of Geodesy and Photogrammetry Meets Machine Vision, Eth-Hoenggerberg, CH-8093, Zurich, Switzerland; (41+1) 377 3051.

First European Working Conference on VHDL Methods (COMP); Sept. 4-7; Institute Méditerranéan de Technologie, Marseille, France; Petra Michel, Siemens AG, Department AFE Isea1, Otto Hahn Ring 6, Munich 83, West Germany.

International Conference on Application Specific Array Processors (COMP); Sept. 5-7; Princeton University, New Jersey; S.J. Kung, Department of Electrical Engineers, Princeton University, Princeton, N.J. 08544; 213-812-0790.

International Test Conference (COMP); Sept. 9-13; Sheraton Washington Hotel, Washington, D.C.; Doris Thomas, ITC, Box 264, Mount Freedom, N.J. 07970; 201-895-5260.

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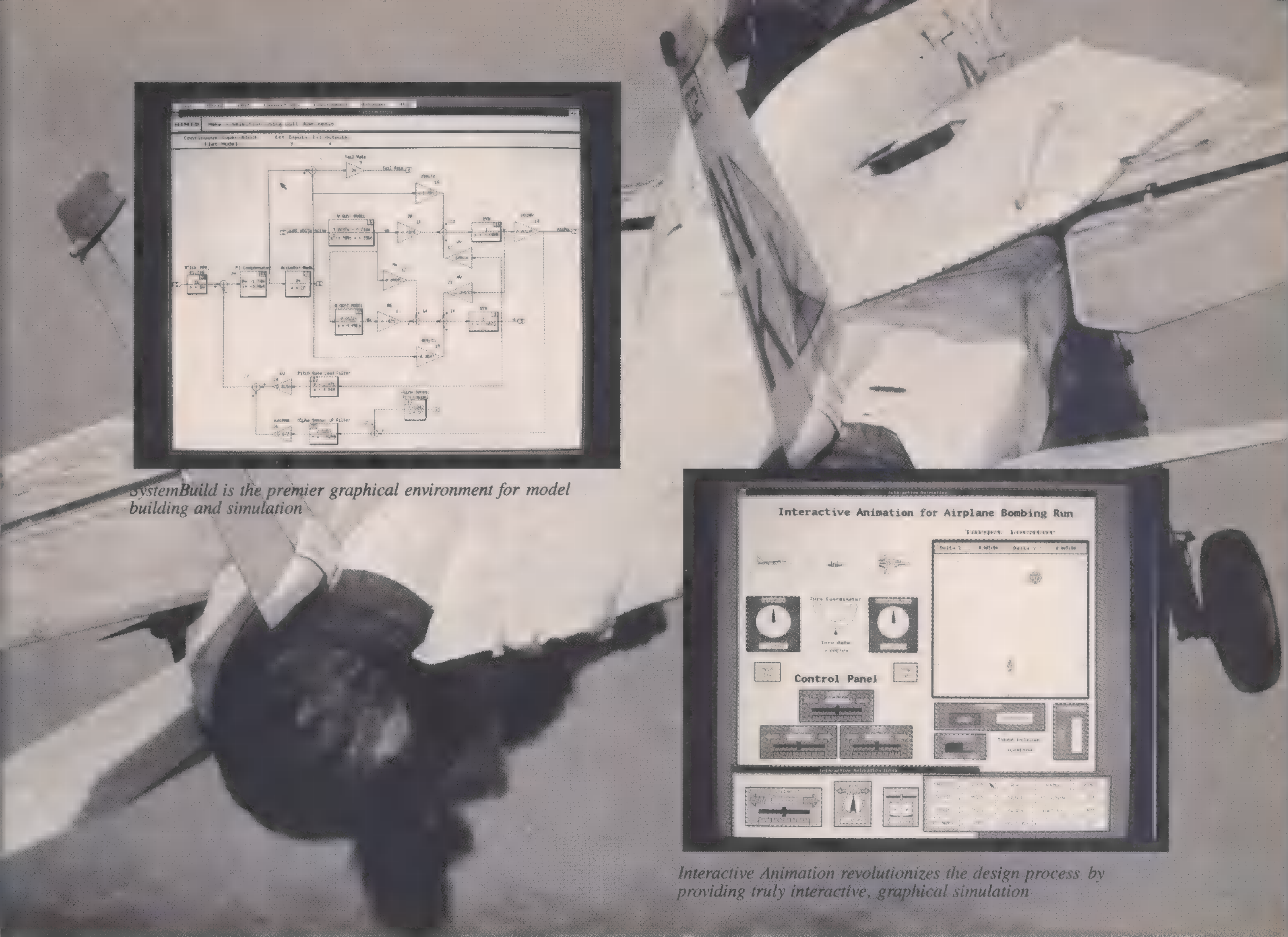

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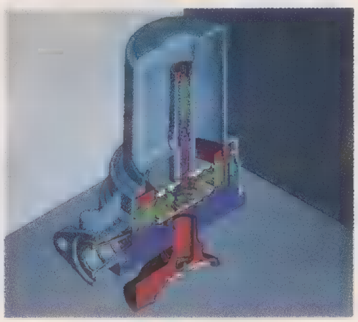

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CALENDAR

(Continued from p. 14B)

12th Semiconductor Laser Conference (IEEE/LEO); Sept. 9-15; Congress Center, Davos, Switzerland; Hans Melchior, Institute for Quantum Electronics, Swiss Federal Institute of Technology, Ch-8093, Zurich, Switzerland; (41+1) 377 2101.

Managing Expert System Programs/Projects (COMP); Sept. 10-12; Washington, D.C.; IEEE Computer Society, Conference Services, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036; 202-371-0101.

Petroleum and Chemical Industry Technical Conference (IA); Sept. 10-12; Westin Galleria Hotel, Houston, Texas; J. R. Zahn, Reliance Electric Co., 340 N. Belt East, Suite 199, Houston, Texas 77060; 713-931-8100.

10th International Conference on Conduction and Breakdown in Dielectric Liquids (DEI); Sept. 10-14; Grenoble, France; R. Tobazeon, C.N.R.S.-L.E.M.D., 25 Ave. des Martyrs-166 X, 38042 Grenoble Cedex, France; (33+7) 688 1071.

Midcon '90 (Region 4 et al.); Sept. 11-13; Dallas Convention Center, Dallas; Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, Calif. 90045; 213-772-2965.

12th Annual Electrical Overstress and Electrostatic Discharge Symposium (CHMT et al.); Sept. 11-13; Buena Vista Palace, Orlando, Fla.; Ted Dangelmayer, 4 Timberland Rd., Plaistow, N.H. 03865; 508-960-5272.

International Professional Communication Conference (PC); Sept. 12-14; The Post House Hotel, Guildford, England; John B. Moffett, The Johns Hopkins University, Applied Physics Laboratory, Building 4, Room 379, Johns Hopkins Road, Laurel, Md. 20707; 301-953-5000, ext. 8260.

International Conference on Computer Design: VLSI in Computers and Processors–ICCD '90 (COMP); Sept. 16-19; Hyatt Regency Cambridge, Cambridge, Mass.; Edward M. Middlesworth, Hewlett-Packard Co., Building 250, Box 10350, Palo Alto, Calif. 94303; 415-857-5485.

16th European Conference on Optical Communication (LEO); Sept. 16-20; International Congress Centre RAI, Amsterdam, the Netherlands; B. H. Berbeek, Philips Research Laboratories, Box 80.000, 5600JA Eindhoven, The Netherlands; (31+40) 743 240.

Bipolar Circuits and Technology Meeting (CAS et al.); Sept. 17-18; Marriott City Center Hotel, Minneapolis, Minn.; Jan Jopke, 6611 Countryside Dr., Eden Prairie, Minn. 55346; 612-934-5082.

Autotestcon '90 (AES et al.); Sept. 17-21; San Antonio Convention Center, Texas; Bob Hershey, SA-ALC/SCC, Kelly Air Force Base, San Antonio, Texas 78241; 512-925-7313.

ASIC Seminar and Exhibit (Rochester Section, COMP); Sept. 17-21; Rochester Riverside Convention Center, Rochester, N.Y.; Kenneth Hsu, Department of Computer Engineering, Roch-

(Continued on p. 14H)

(Continued from p. 14F)
ester Institute of Technology, Rochester, N.Y. 14623; 716-475-2655.

Electronic Publishing '90 (COMP); Sept. 18-20; Potomac Sheraton, Gaithersburg, Md.; Peter R. King, Department of Computer Science, University of Manitoba, Winnipeg, Man. R3T 2N2, Canada; 204-474-9935.

40th Annual Broadcast Symposium (BT); Sept. 20-21; Washington Hotel, Washington, D.C.; Otto R. Claus, WBAL-TV, 3800 Hooper Ave., Baltimore, Md. 21211; 301-338-6455.

International Broadcasting Convention (Region 8 et al.); Sept. 21-25; Brighton, England; IBC Secretariat, Institution of Electrical Engineers, Savoy Place, London WC2R OBL, England; (44+1) 240 1871.

Sixth International Symposium on Gaseous Dielectrics (DEI, PE); Sept. 23-27; Hyatt Regency, Knoxville, Tenn.; D. L. McCorkle, Oak Ridge National Laboratory, Building 4500S, MS 6122, Box 2008, Oak Ridge, Tenn. 37831; 615-574-6199.

Oceans '90 (OE); Sept. 24-26; Washington Convention Center, Washington, D.C.; Anthony Eller, Science Applications International Corp., 1710 Goodridge Dr., Box 1303, McLean, Va. 22102; 703-734-5880.

Region 10 Conference on Computer and Communication Systems-Tencon '90 (Region 10 et al.); Sept. 24-27; Hong Kong Convention Center, Hong Kong; P. S. Chung, Department of Electronics, Chinese University-Hong Kong, Shatin, N.T. Hong Kong; (85+90) 695 2699.

Computational Intelligence '90 (COMP et al.); Sept. 27-29; University of Milan, Milan, Italy; Giorgio Valle, University of Milan, Dip. Scienze della Informazione, via Noretto 20133, Milan, Italy.

Military Communications Conference-Milcom '90 (COM); Sept. 30-Oct. 3; Hyatt Regency Monterey, Monterey, Calif.; T. A. Goncharoff, 0/62-42, B/076, Lockheed Missiles & Space Co., Box 3504, Sunnyvale, Calif. 94088; 408-756-5630.

Latincon '90 (Mexico, Region 9); Sept. 30-Oct. 4; Monterrey, Mexico; J.L. Apodaca, CFE-Ave., Universidad 2400 Nte., Monterrey, N.L. 64000, Mexico; (52+83) 74 13 13; fax, (52+83) 74 11 55.

OCTOBER

Eurosensors IV '90 (West German Section); Oct. 1-3; Kongresszentrum, Karlsruhe, West Germany; P. Stilke, VDE Zentralstelle Tagungen, Stresemannallee 15, D-6000 Frankfurt/Main 70, West Germany; (06+9) 630 8202.

Ninth CHMT International Electronic Manufacturing Technology Symposium (CHMT); Oct. 1-3; Ramada Renaissance Hotel, Washington, D.C.; Bill Moody, 2529 Eaton Rd., Wilmington, Del. 19810; 302-478-4143.

International Conference on Information Technology-Info Japan '90 (COMP et al.); Oct.
(Continued on p. 14L)

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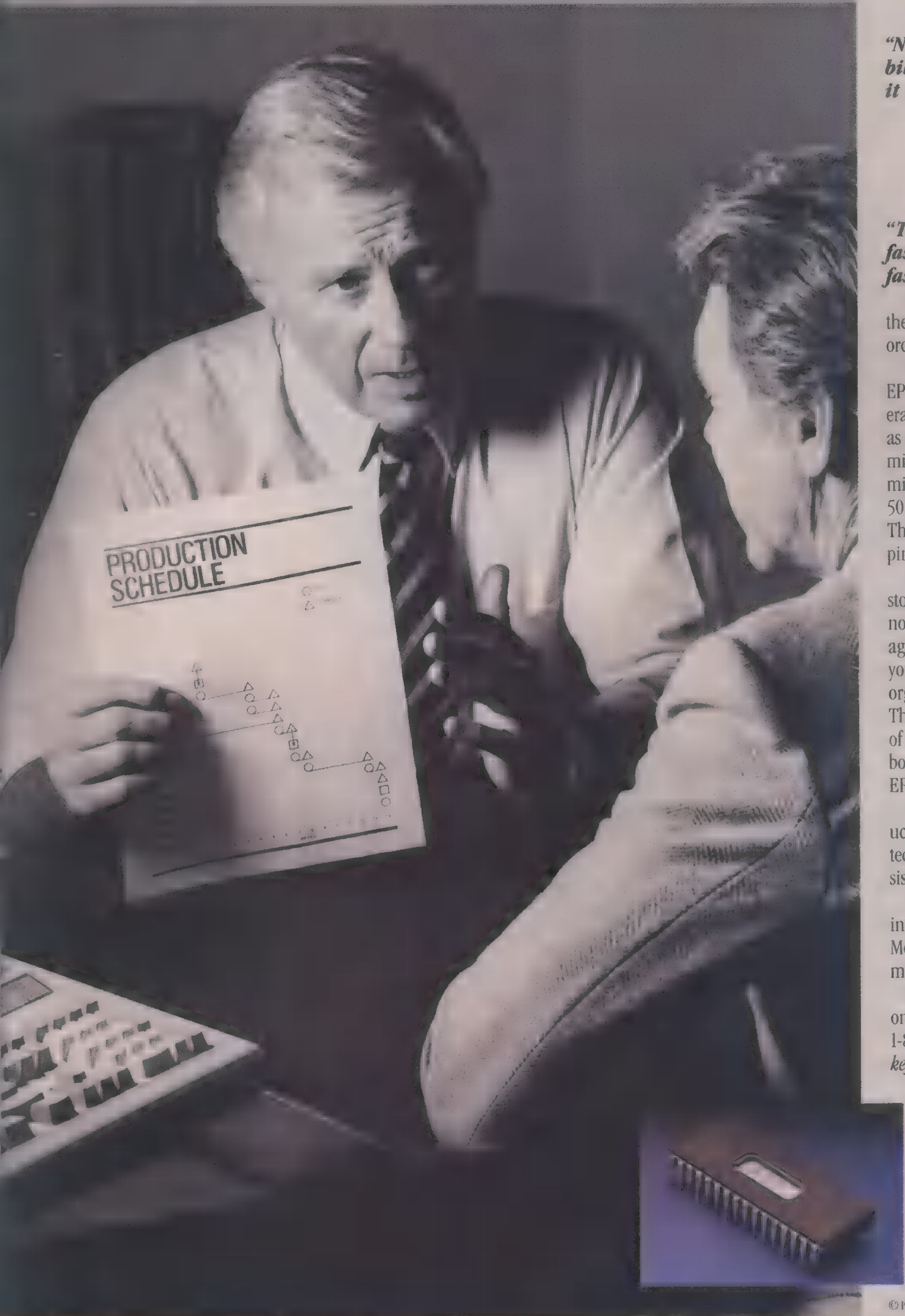

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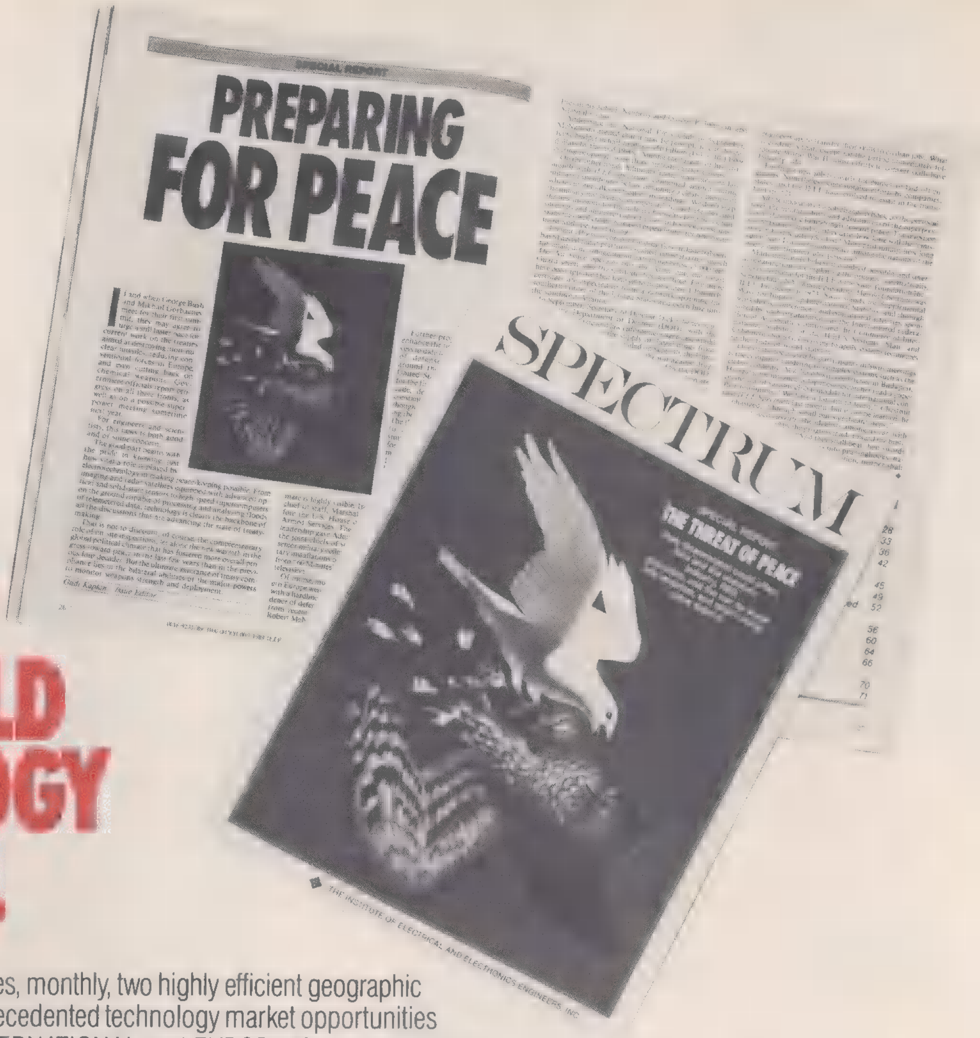
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CALENDAR

(Continued from p. 14H)
1-5; Keio Plaza Intercontinental, Tokyo; Takuma Yamamoto, Fujitsu Ltd., 3-14-1 Hiyoshi, Kohoku-ku, Yokohamashi, Japan.

Sixth International Conference on the Application of Standards for OSI (COMP); Oct. 2-4; Gaithersburg, Md.; Joan Wyrwa, NIST/OST, Room B217, Building 225, Gaithersburg, Md. 20899; 301-975-3643.

International Conference on Harmonics in Power Systems (PES); Oct. 4-6; Budapest Technical University, Hungary; Andras M. Dan, Department of Power Systems, Budapest Technical Institute, 1111 Budapest, Egry Jozsef u. 18, Hungary; (36+1) 666 438.

Workshop on Visual Languages (COMP); Oct. 4-6; North Short Hilton, Skokie, Ill.; Stefano Levialdi, Department of Mathematics, University of Rome, Piazzale Aldo Moro 2, 00185, Rome, Italy.

Sections Congress '90: Optimizing Connections in the IEEE Family (IEEE Regional Activities Board); Oct. 5-7; Royal York Hotel, Toronto; T.H. Burns, Field Services, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 201-562-5514; fax, 201-981-0027.

Industry Applications Society Annual Meeting (IA); Oct. 7-12; Westin Hotel, Seattle, Wash.; Richard W. Becker, Engineered Electrical Systems Inc., 201 J.S. Ditty Building, Bellevue, Wash. 98004; 206-454-5440.

Capacitor and Resistor Technology Symposium–CARTS-Europe '90 (CHMT); Oct. 8-10; The Pullman Hotel, Bordeaux, France; Jack Westwood, CARTS-Europe, 50 Wiltshire Gardens, Bransgore, Christchurch BH23 8BJ, England; (44+4) 257 3578.

Frontiers '90 (COMP, NASA); Oct. 8-10; University of Maryland, College Park; Johanna Weinstein, UMIACS, University of Maryland, A.V. Williams Building, College Park, Md. 20742; 301-454-1808.

Future Trends '90, Workshop on Future Trends of Distributed Computing Systems (COMP); Oct. 8-10; Cairo, Egypt; Stephen Yau, University of Florida, CIS Department, 301 CSE, Gainesville, Fla. 32611; 904-335-8006.

Northcon '90 (Portland, Seattle Sections); Oct. 9-11; Seattle Center, Seattle, Wash.; Alexes Razevich, Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, Calif. 90045; 213-772-2965.

Ninth Symposium on Reliable Distributed Systems–SRDS (COMP et al.); Oct. 9-12; Huntsville Marriott, Huntsville, Ala.; Raif M. Yanney, Trio, 1 Space Park DH2/2328, Redondo Beach, Calif. 90278; 213-764-6033.

International Carnahan Conference on Security Technology (AES, Lexington Section); Oct. 10-12; Carnahan Conference Center, University of Kentucky, Lexington; L. McGill, Box 23961, Lexington, Ky. 40523; 606-223-8580.

Fifth Workshop on Spectrum Estimation and Modeling (ASSP); Oct. 10-12; The Lodge at Woodcliff, Rochester, N.Y.; M. R. Raghuveer, Rochester Institute of Technology, Department of Electrical Engineering, 1 Lamb Memorial Drive, Box 9887, Rochester, N.Y. 14623; 716-475-2185.

Gallium Arsenide Integrated Circuits Symposium (ED, MTT); Oct. 21-24; Hyatt Regency Hotel, Atlanta, Ga.; Kenneth J. Sleger, Naval Research Laboratory, Code 6852, Washington, D.C. 20375; 202-767-3894.

International Telecommunications Energy Conference–Intelec '90 (COM); Oct. 21-24; Orlando, Fla.; Jim Fletcher, 41 Robbins Ave., Berkeley Heights, N.J. 07922; 201-464-7919.

Joint Power Generation Conference–JPGC '90 (PE et al.); Oct. 21-25; Park Plaza Hotel, Boston; Marisa Scalice, American Society of Mechanical Engineers, 345 E. 47th St., New York, N.Y. 10017; 212-705-7053.

Conference [redacted] Electromagnetic Field Computation–CEFC '90 (Region 7); Oct. 22-24; Westbury Hotel, Toronto; M. Thompsett, Faculty of Applied Science, University of Toronto, Toronto, Ont. M5S 1A4, Canada; 416-978-6528.

International Engineering Management Conference–EM '90 (CHMT, EM); Oct. 22-24; Marriott Hotel, Santa Clara, Calif.; Judith Baar, 620 Abbie Court, Pleasanton, Calif. 94566; 415-484-4745.

(Continued on p. 50F)

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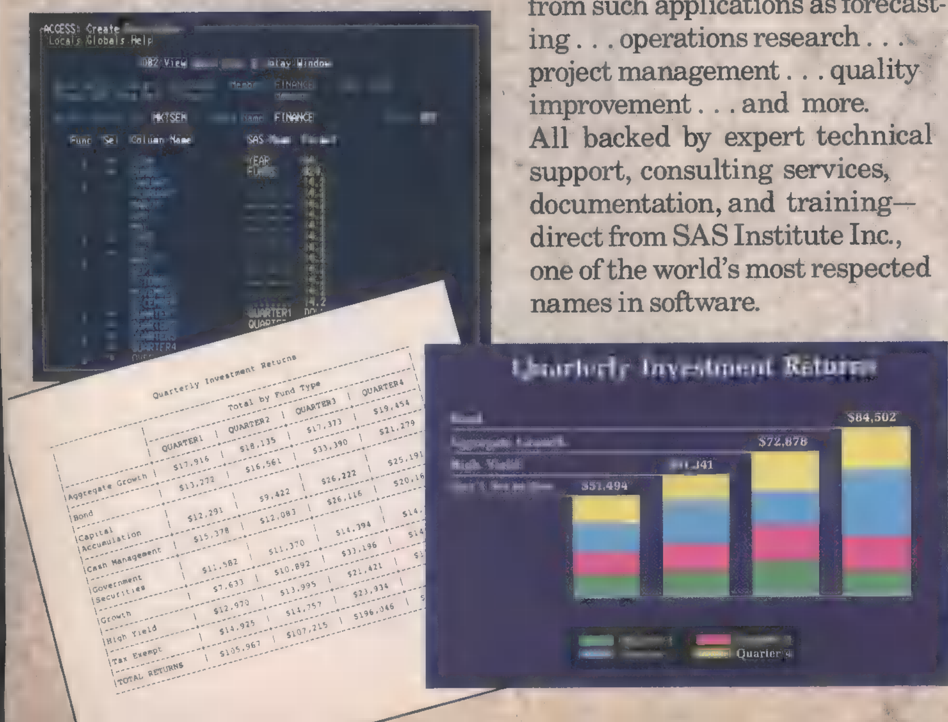

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Ethics case revisited

Recently, we posed the case of the three engineers who, employed by a consulting firm that bid on a communications system for a municipality, were then offered the job directly by an official of the municipality and accepted it [April, p. 19]. The case was adjudged by the ethics committee of the National Society of Professional Engineers (NSPE) to represent no violation of the society's Code of Ethics. The board's conclusion was based on the Code's placement of the public interest ahead of other considerations.

All of the readers who wrote to us about this case—many of them registered professional engineers—disagreed with the NSPE board's decision. Most were unequivocal, criticizing equally the city and the engineers. Several commented on the NSPE committee's definition or interpretation of "the public interest."

R. B. Kircher, a process engineer from Portland, Ore., wrote "Public interest!? Balderdash! The municipality is just another business. They deserve no special privilege. The engineers represented the firm and without prior consent, the proposal belonged to the firm. Period!"

Richard Macchi, a registered professional engineer from Attleboro, Mass., voiced his opinion that acceptance of a contract by the three engineers without approval of their former firm is unethical. "The fact that the client is a municipality is irrelevant—bad faith actions by the city do not justify similar behavior by the engineers," he wrote.

A registered professional engineer in Ohio, Richard H. Engelmann, while granting that the public interest should take precedence, stated that "the public deserves to be served by people who do not steal from their employers, and by people who do not urge others to steal from their employers."

In the view of David C. Lincoln of Phoenix, Ariz., the serious ethical breach was primarily on the part of the city. "It is entirely unacceptable to have one standard of ethics for the private sector and a lower standard for the public sector," he wrote.

A White Plains, N.Y., registered professional engineer, Irwin B. Margiloff, wrote that "to hold that the 'public interest' is paramount is shortsightedly to define public interest as pertaining only to this particular project, not to the long-term advantages of having willing bidders on municipal work . . ." The NSPE position, he said, is "wrongheaded, immoral, destructive of long-term productive use of resources, unfair to business[es], and to the professionals who build them."

Jeff Belagus of Winnipeg, Man., Canada, viewed the city official as unworthy of being called a "good corporate citizen," but not as acting in an unethical way. The engineers, however, he said, were unethical. When placed by the city official in a position where they had a choice, they chose the unethical option, he said.

A number of readers saw the case as involving law, rather than ethics. Patrick J. O'Connor, a professor at the Devry Institute of Technology in Chicago, wrote: "In leaving the consulting firm to negotiate separately with the municipal official, the engineers in the example would be involved in a breach-of-contract situation with every consulting firm I am aware of. The municipal official thus becomes an accessory to the breach of contract." The violation would be against the contractual clause that forbids an employee from working for a client of the consulting firm, or leaving the firm to take a job with one of its clients, for a specific amount of time after the employee stops working for the firm, O'Connor noted. In such a case, he said, he would expect both the engineers and the city official to be sued by the consulting firm.

Additional comments received on the case will appear in Forum in future issues.

NASA goofed again

NASA seems to get into trouble in the "soft" technologies, like knot tying and caulking. Its track record is extremely good in the high technologies—notably electronic systems and computer programming.

The latest eyebrow-raising episode was the poorly lashed-down antenna cable on one of the Hubble Space Telescope's high-gain antennas. Tied in the wrong place to the antenna mast, the cable limited the rotation of the antenna about one axis—to 78 degrees instead of the intended 100 degrees.

Post-error computer analysis by the space agency confirmed the cause of the problem. The actual rotation was not tested prior to launch because the low-torque motors required in space could not budge the antennas in the earth's gravitation field at ground level.

Belatedly, NASA produced a full-scale mockup using polystyrene, which further substantiated the fault.

In the 1986 *Challenger* accident, puttied rocket joints were found to be defective.

In 1973, a meteoroid shield was ripped off during the launch of Skylab I. The engineers had failed to consider the aerodynamic stresses on the shield.

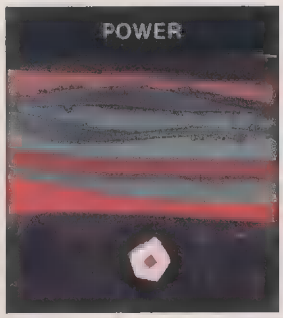
Of the many boards of inquiry convened after the various NASA mishaps, one had some particularly sound advice for the agency and its contractors. It was a warning not to be overwhelmed by the necessary emphasis on detailed design of complex subsystems, but to stand back once in a while to ask "what do you think?" Doing so, the inquiry board suggested, would avoid suppressing the role of the intuitive engineer, which otherwise might result from the necessarily complex "management system."

The old-fashioned chief engineer who scans the entire project and its progress while individual team members are involved in the detailed design of its different components might have avoided one or more of the NASA errors.

—Donald Christiansen

Nuclear waste: the challenge is global

Those seeking to dispose of it are finding the world is a patchwork of backyards—and no one wants it in theirs



The discovery of nuclear fission has in a few decades produced weapons of awesome power, electricity to fuel growing economies, submarines that roam the world's oceans, and new medical techniques and treatments. But along with these highly visible artifacts of the nuclear age has come a less conspicuous one: many millions of tons of nuclear waste, comprising radioactive elements with half-lives ranging from microseconds to eons.

Management of this waste concerns the military, electric-utility, and political establishments of countries around the globe. About 30 nations use nuclear energy to generate one-sixth of the world's electricity. Some 530 nuclear power reactors are now in operation, and another 96 are under construction, according to the International Atomic Energy Agency (IAEA), an intergovernmental organization affiliated with the United Nations and based in Vienna, Austria.

In North America, Europe, and Asia, all of which have significant nuclear generation, supporters hope that new and simplified, comparatively standardized reactors will spur a renaissance in nuclear technology and in public support of it. But there is wide agreement that in most places any such renaissance awaits more consistent and coherent Government policies on managing waste. Only last Nov. 28, U.S. Deputy Secretary of Energy W. Henson Moore told a group of top nuclear industry executives: "We must solve the nuclear waste problem if the public is to accept commercial nuclear power."

Progress in disposing of the longest-lived, or high-level, nuclear wastes has stalled almost everywhere. No country currently has a permanent repository for such materials. In the meantime, the waste keeps piling up.

Three kinds of waste

The IAEA recognizes high-, intermediate-, and low-level forms of nuclear waste. The classification is based on several factors, including the waste's source and temperature, and half-life: the greater the number of long-lived radioisotopes the waste contains, the higher the level of waste. (Generally speaking, a long-lived isotope is one with a half-life of more than 30 years.)

High-level waste is produced in two ways: by reprocessing spent nuclear fuel to recover isotopes that can be used again as fuel, and by merely using a reactor's fuel rods, which contain long-lived isotopes when spent. This waste is also at first very hot.

Intermediate-level waste consists of reactor byproducts and other materials, including equipment and tools that have become radioactive. It is less radioactive and less hot than the high-level type, but cannot be handled or transported without shielding.

Low-level waste, which can be handled without shielding, comes largely from commercial-power, medical, and other nonmilitary sources, and consists mainly of ordinary refuse (metal, glass, paper, rags, and the like) that has been contaminated by radioactive materials. Though the least harmful, low-level waste is also by far the most voluminous.

According to estimates by the IAEA and another international group, the Paris-based Nuclear Energy Agency of the Organization for Economic Cooperation and Development, some 370 000 cubic meters of low-level waste will accumulate this year from commercial nuclear power plants alone. For intermediate- and high-level waste, the figures are 26 400 and 3400 m^3, respectively. By 1995, with more plants on line, the IAEA expects high-level waste to be piling up at a rate of 3800 m^3 per year.

Military makes more

Although, overall, wastes from commercial power reactors outweigh those from military ones, military programs produce a huge excess of the high-level type. Much of this is concentrated in the United States and the Soviet Union, which have by far the most extensive weapons and submarine-propulsion programs. In the United States, according to the U.S. Department of Energy (DOE), the military has produced about 380 000 m^3 of high-level waste, whereas commercial reactors have produced about 8000 m^3, including spent fuel (which contains long-lived radioisotopes and so is handled much like high-level waste).

The military figure is significant because this kind of waste is the hardest to manage. In most countries with substantial nuclear establishments, R&D on permanently storing it is now the most costly and time-consuming activity in the nuclear-waste field.

Because they generate heat, high-level wastes must be kept cool

Defining terms

Actinides: elements with atomic numbers between 89 and 103.
Alpha particle: a positively charged particle made up of two neutrons and two protons, identical to the nucleus of a helium atom.
Beta particle: a negatively charged particle with a short range in air and a low penetrating ability.
Gamma rays: highly penetrating short-wavelength electromagnetic radiation.
Half-life: the time in which a radioactive material loses half of its radioactivity by decay.
Radionuclide, radioisotope: an isotope that decays toward a stable state by emitting ionizing radiation.
Spent fuel: fuel that has been used in a reactor.
Reprocessing: the chemical dissolution of spent reactor fuel to recover fissile material; it generates highly radioactive wastes that must be solidified for final disposal.
Transuranic wastes: nuclides with atomic numbers greater than 92, wastes contaminated with uranium-233 and its daughter products, and some isotopes of plutonium.

Glenn Zorpette Associate Editor
Gary Stix Associate Editor

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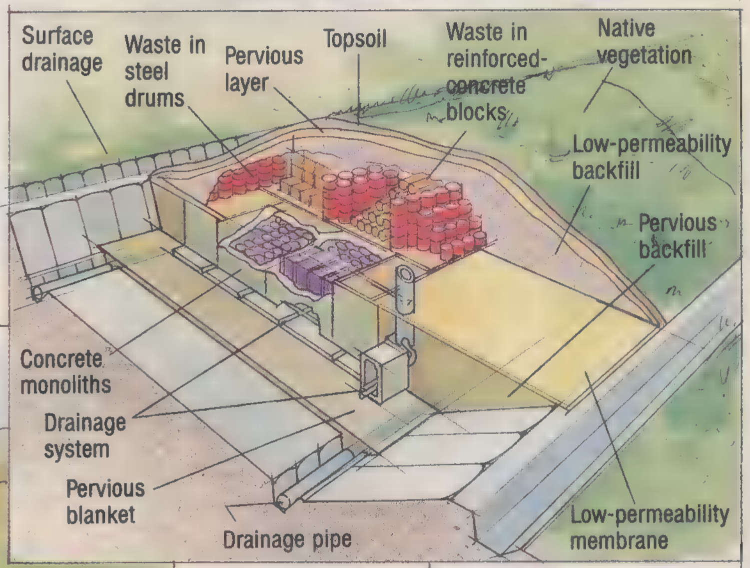
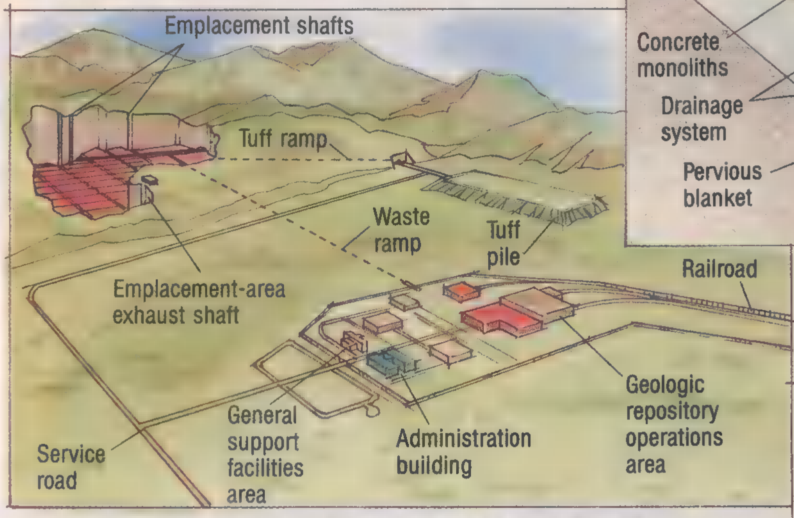
Atomic Energy of Canada Ltd.

Containers with a titanium shell have been developed in Canada for burial of spent-fuel assemblies. According to Atomic Energy of Canada Ltd., they should keep out groundwater in a site with typical Canadian geology for at least 500 years.

Low-level waste disposal

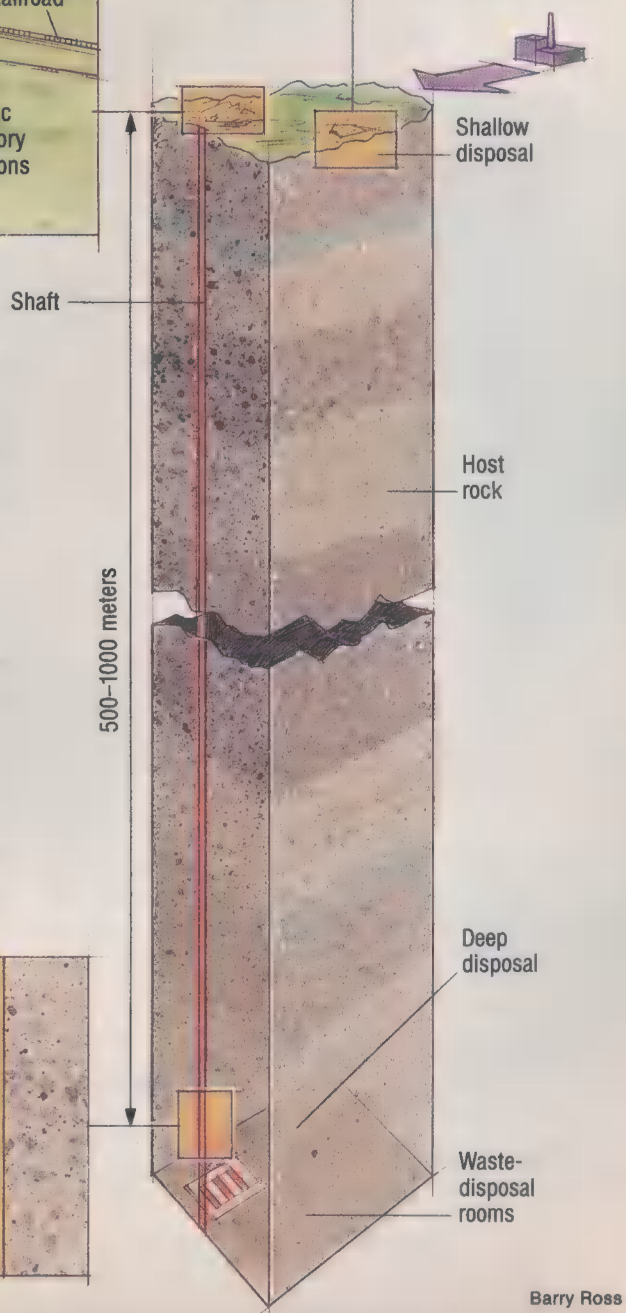


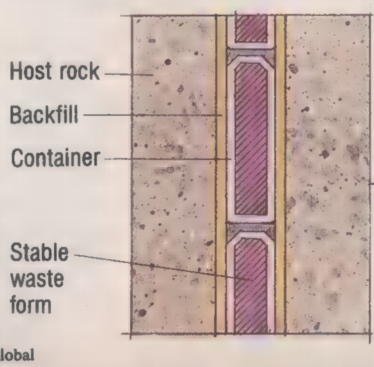


Temporary surface storage facility

Multiple barriers are designed to isolate high- and low-level nuclear wastes for up to tens of thousands of years. Low-level waste is usually stored in shallow disposal facilities. In the earth-mounded concrete-bunker type (right inset), crushed steel drums are encased in concrete blocks, or monoliths. More waste in metal drums or concrete containers is stacked on top. All is then covered with low-permeability backfill intended to prevent the radionuclides from escaping into groundwater. A drainage system diverts rainwater.

No repository for long-lived wastes has yet been constructed, though the Waste Isolation Pilot Plant in Carlsbad, N.M., is undergoing tests. The site chosen is likely to be excavated to several hundred to a thousand meters. Spent-fuel rods or vitrified reprocessed wastes will be put in a temporary holding area (above), for transfer from transport casks into metal canisters. One option (right) is to lower the canisters in a shielded transporter on a remotely controlled elevator to the emplacement rooms. Unmanned, automatic vehicles will carry the canisters to holes in the ground or wall spaced several meters apart, to prevent heat from building up. When full, the waste-emplacement rooms—and the shaft itself—may be backfilled with the rock mined in excavating the repository (below).





Barry Ross

for years after they are produced. The long-lived radioisotopes they contain emit alpha and beta particles and gamma radiation, all harmful in even small doses. Thus, they cannot be handled directly and must be isolated from human and environmental contact for many thousands of years.

For handling spent rods from commercial reactors, the common practice is to store them in cooling pools at the power plants where they were used. When they cool off enough and more room is needed in the pool, they are sent either for reprocessing or else for dry storage, usually in concrete or steel casks on the reactor site.

Such storage is considered an interim solution and geologists and engineers are now investigating, or drawing up detailed plans for, permanent disposal of high-level wastes underground—typically within certain geologic formations of volcanic ash, granite, or salt, which are believed to be stable over thousands or even millions of years. In France, Great Britain, and the United States, though, wherever and whenever sites have been considered, progress has been halted by the intense opposition of local authorities and residents to the disposal of high-level wastes near them.

Europe favors reprocessing

Liquid high-level wastes are produced by the reprocessing of nuclear fuel to recover fissionable products for reuse in reactors. The main fissionable materials involved are isotopes of uranium and plutonium with respective atomic weights of 235 and 239.

Commercial reactors are powered by fuel containing 1.6–5.5 percent U-235. But after use in a reactor, 95 percent of the uranium, containing 0.3–2 percent U-235, as well as other fissionable isotopes, remains and can be used again, notes William H. Hannum, a nuclear waste expert at Argonne National Laboratory in Argonne, Ill. The military reactors that propel nuclear submarines, on the other hand, use more highly enriched fuel, with 93 percent U-235; what percentages of this fissionable material remains after use is not public knowledge.

Reprocessing is an integral, if often embryonic, part of the nuclear establishments of most European countries and Japan. In the United States, reprocessing is part of the military fuel cycle but, after a discouraging history in the commercial sector, has been deemed uneconomical there.

Small, experimental reprocessing facilities have been operated in West Germany, Belgium, India, and Japan, as pilot plants for larger commercial reprocessing facilities (although West Germany and Belgium have for the time being abandoned their plans for larger plants). Only France—where 70 percent of the electricity is nuclear-generated—and Great Britain currently operate such plants on a commercial basis. Both countries reprocess spent fuel from reactors in a half-dozen or so other nations as well as their own.

Hot, high-level waste is created during the first few stages of reprocessing, when uranium and plutonium are separated from spent fuel, leaving behind dozens of long-lived radioisotopes in a solution of nitric acid [see "Learning from nature," p. 23]. This solution is then diverted to stainless steel tanks, which are equipped with cooling systems. The liquid may also be treated to neutralize it and precipitate the radioactive elements, forming a sludge.

A number of leaks of this liquid have occurred at Government sites in the United States since the mid-1950s (in Great Britain, there have been leaks of intermediate-level waste). Some have been highly publicized, and the ensuing public outcry and political ramifications have greatly complicated waste management.

Nonetheless, industry officials believe there is a technical solution: melting powdered glass with dried, concentrated high-level wastes, a procedure known as vitrification. Early experiments were carried out in Canada about 30 years ago and in the United States more recently, while the process has been used on a large scale in France for more than a decade and in Belgium for more than five years [see "Learning from nature," p. 23]. Inspired partly by this success, both the United States and Great Britain plan to begin vitrifying high-level wastes within two years.

Vitrification isolates radioisotopes from the environment by enveloping them in glass, which is relatively impervious to other substances even on an atomic level and impedes leaching of the isotopes into groundwater. The glass containing the waste is in turn sealed within specially designed stainless steel canisters. The entire system is predicated on finding a permanent, deep underground site for the canisters, something researchers and government officials have been unable to do, mainly for political reasons.

Although vitrification is being embraced by nuclear experts around the world, scientists in Australia, which operates no nuclear power plants, are convinced they have a better way: sealing the waste within a form of synthetic rock, or "synroc," created from three titanate minerals and a little metal alloy. The technology was invented 10 years ago by a group led by A.E. Ringwood at the Australian National University in Canberra. Several independent researchers have found synroc-clad waste superior to vitrified waste in important characteristics, including durability, resistance to leaching and irradiation by neutrons, and suitability to burial in deep boreholes.

Despite these advantages, synroc has yet to win converts among Western nuclear nations. However, interest is reportedly high in the Soviet Union, which operates 73 reactors, and a complex deal to build a commercial synroc plant there with U.S. financing has been proposed. Half of the waste treated at the plant would come from the Soviet Union, the rest from outside the country, providing a return for investors. The deal apparently hinges on approval by Government officials in both Australia and the USSR.

Lacking a permanent repository, French vitrified wastes are now being stored in air-cooled vaults containing compartments with multilayer tubes. Each consists of a plugged inner tube, which holds the waste, while cooling air is circulated in a surrounding outer tube. A vitrification plant about to begin operation in the United Kingdom will use a similar arrangement, as will several sites in the United States.

Some countries, including West Germany and the United Kingdom, are operating centralized, temporary storage sites, called AFR, or away-from-reactor, for high-level wastes. In AFR storage, the wastes can be recovered for final disposal. The Canadians and Swiss are planning such facilities.

Trouble underground

Despite widespread public opposition, evaluation of prospective permanent disposal sites is under way in many countries. The only type actively under consideration for long-term disposal is a deep-geological repository, excavated several hundred to 1000 meters below the surface. None is expected to begin storing wastes until after the year 2010—and possibly much later because of the controversy that usually surrounds any discussions in this field.

Designing a repository must take into account seismic, volcanic, hydrologic, and geochemical characteristics of the surrounding geologic formation to ensure that the wastes are isolated virtually indefinitely. The key technical issue is preventing radioactive material from contaminating groundwater, which could poison food and drinking water; so water flux, velocity, and flow path at a prospective site are carefully studied in different geological formations. The repository must also be engineered to remove the heat generated by high-level waste. The possibility of human intrusion is another important risk factor.

Unbitten bullets

Because of the issue's politically charged nature, some nations have formally elected to defer a final decison. In February, as a result of protests over the choice of a site that would begin operating sometime in the next decade, France declared a one-year cooling-off period before a decision is made. The United Kingdom, after protests by antinuclear groups, decided to postpone choosing an active site until at least the year 2050.

In crowded, resource-poor Japan, public opinion has generally favored nuclear power because of the country's drive for ener-

gy self-sufficiency. But in 1988, during a commemoration two years after the Chernobyl accident, protests erupted over the Rokkasho reprocessing facility and low-level waste-disposal site. Opposition, too, has arisen over a planned Storage Engineering Center at Horonobe on the northern island of Hokkaido. Although Japan's Atomic Energy Commission says this will be merely to study disposal technologies, local opponents fear it may in the end become an actual dumping site.

The United States is farthest along in planning for the long term, but its haste may prove costly. DOE has constructed a repository, the Waste Isolation Pilot Plant (WIPP), in Carlsbad, N.M., intended for mainly transuranic wastes (nuclides with atomic numbers greater than 92), some of which survive for many centuries. And DOE's plan to investigate a site for high-level wastes at the proposed Yucca Mountain repository in Nevada has bogged down in legal conflict with the state.

The need for an expedited solution is debatable. One of the main arguments for pushing ahead is ethical: that the people that generate the waste should be the ones to find a final resting place not requiring constant care by future generations.

A main counterargument—put forward by both environmentalists and some technical experts—is that there is no pressing need for a deep repository: the technology exists to store the wastes on the surface; this lets them cool significantly until they are eventually disposed of underground.

The capacity of existing storage sites can, in fact, be expanded. Replacing the original aluminum storage racks that hold fuel assemblies in storage pools with new racks made of more expen-

Storage of commercial spent fuel and high-level waste in nine countries

Country	Nuclear capacity, gigawatts (proportion of electricity generated)[a]	Number of reactors[a]	Reprocessing (where)	Interim storage			Institutional responsibility[g]	Repository schedule
				Locations	Methods	Duration, years		
Canada	12.2 (15.6%)	18	No[b]	Reactor sites	Wet pools, perhaps dry casks[d] at Pickering, Ont.	>50	Utilities	>2010
France	52.6 (74.6%)	55	Yes	Reactor sites	Wet pools	~1	EDF	>2010
				Reprocessing plants	SF–wet pools HLW–dry vaults	~2 >20	Cogéma	
West Germany	22.7 (34.3%)	24	Yes (WG, Fr, UK)	Reactor sites	Wet pools	3–10	Utilities	~2008
				Independent facility[c] (Gorleben, Ahaus)	SF–dry casks[e] HLW–dry casks[e]	Undecided >10	Utilities (through BLG)	
Japan	29.3 (27.8%)	39	Yes (Fr, Ja, UK)	Reactor sites	SF–wet pools[e]	2–3	Utilities	>2030
				Reprocessing plants	SF–wet pools HLW–undecided	~4 30–50	Utilities (through JNFS)	
Spain	7.54 (38.4%)	10	No	Reactor sites	Wet pools	40	Utilities	~2020
				Independent facility (not sited)	Pools and/or dry cask[f]	40	Government corporation (Enresa)	
Sweden	9.82 (45.1%)	12	No	Reactor sites	Wet pools	~1	Utilities	>2020
				Independent facility (CLAB, at Oscarshamn reactor site)	Wet pools	15–40	Utilities (through SKB)	
Switzerland	2.95 (41.6%)	5	Yes (Fr, UK)	Reactor sites	Wet pools	<12	Utilities	>2025
				Independent facility (Würenlingen HLW; SF not under reprocessing contract)	SF, HLW–dry casks[e]	~40	Utilities (through Zwischenlager Gesellschaft)	
United Kingdom	11.2 (21.7%)	39	Yes	Reactor sites	Wet pools	~1	Utilities	>2040
				Independent facility for AGR fuel (at Heysham reactor site)	SF–dry vault	Undecided	Utilities (joint venture)	
				Reprocessing plant	SF–wet pools HLW–dry storage	Few >50	BNFL	
United States	98.3 (19.1%)	110	No	Reactor sites	Wet pools, dry modules	Undecided	Utilities	>2003

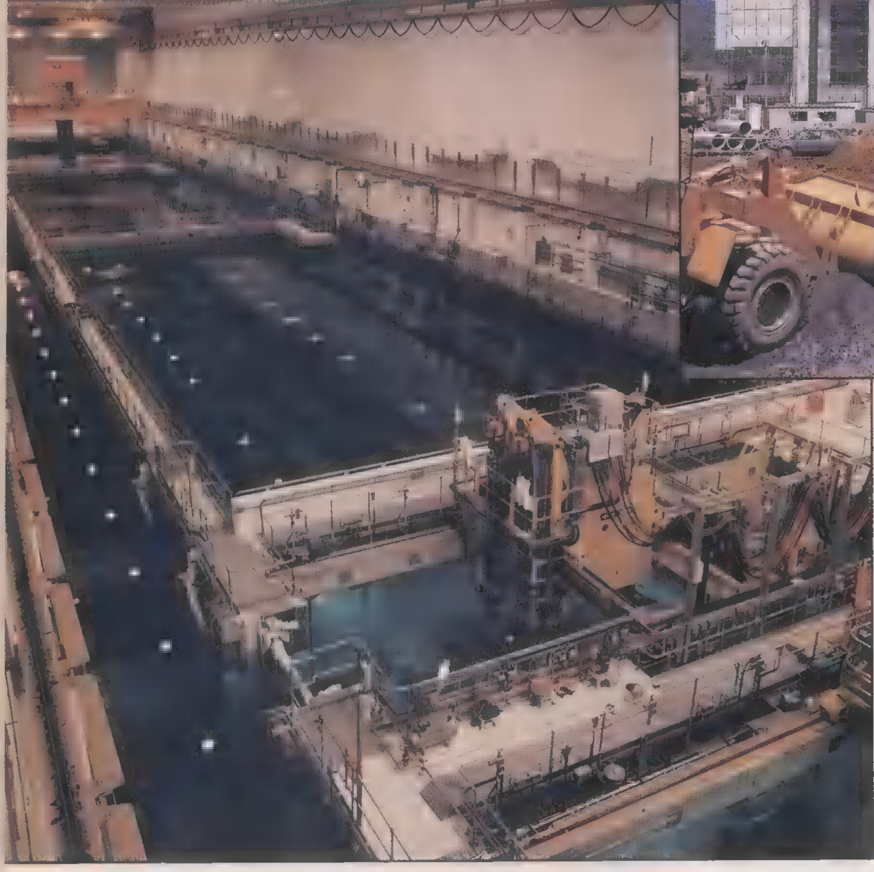
KEY
AGR = advanced gas-cooled reactor
BLG = subsidiary of DWK, which is owned by FRG Nuclear Utilities
BNFL = British Nuclear Fuels PLC
CLAB = central storage for spent fuel
Cogéma = Compagnie Générale des Matières Nucléaires
EDF = Electricité de France
Enresa = Empresa Nacional de Residuos Radiactivos SA
HLW = high-level wastes
JNFS = Japan Nuclear Fuel Services Company
SF = spent fuel
SKB = Svensk Kärnbränslehantering AB

[a] As of Dec. 31, 1989.
[b] No decision about future reprocessing has been made.
[c] A storage facility that does not affect the safety of a nuclear-power or fuel-reprocessing plant.
[d] Transportable storage casks are being investigated for buffer storage.
[e] Transportable storage casks have been selected for the storage facility.
[f] Transportable storage casks are under development as the favored storage technology.
[g] May be private, government, or joint industry-government entities.

Sources: the International Atomic Energy Agency (columns 2 and 3), the Monitored Retrievable Storage Commission, and others

Cross for IEEE Spectrum

A large (800-ton-per-year) reprocessing plant is now under construction near Rokkasho in northernmost Honshu, Japan's main island. In the crowded, resource-poor country, public opinion has generally favored nuclear power because of a national drive for energy self-sufficiency. But in 1988, during a commemoration of the 1986 Chernobyl accident, protests erupted over the proposed Rokkasho facility.



British Nuclear Fuels

Prior to reprocessing, spent-fuel rods are stored under water in pools like this one, Pond 5, at the fuel-handling plant at the Sellafield complex in western Cumbria in the United Kingdom. The rods are kept in the pool for a period ranging from months to years, while the water absorbs heat and short-lived radioactivity. The Sellafield site is the largest of those operated by British Nuclear Fuels PLC, and reprocesses fuels from British as well as Japanese, West German, and other countries' reactors.

sive materials, such as borated steel, can triple capacity. Reracking has been used since the mid-1970s. Licenses for dry storage of spent fuel in steel or concrete casks have been issued to reactor sites since 1986. The advantage of dry storage is that it does not require an active cooling system.

Not in my back yard

When and if the decision is made to proceed with a deep repository, a key factor in gaining acceptance may be public participation. This was apparent at a conference on high-level waste management, held April 8–12 in Las Vegas, Nev. More than 20 papers dealt with the social impact of the problem, and topics often bridged technical and social aspects. One focused on how a public-education program at Sellafield in Cumbria, England, had made the reprocessing and storage site into a major tourist attraction. British Nuclear Fuels PLC calculated that it sent out 8 million invitations to the site.

Canada also has drawn worldwide attention for its care in choosing sites for low-level wastes. The Government has sought communities that would volunteer to accept the wastes, and which would benefit from the jobs that the facility would bring. Ten municipalities have stepped forward, and all have been given the option of backing out at any point.

The process that started with low-level wastes is also seen as a model for how to pick a repository for long-lived wastes. "We believe that, as long as we don't insist on putting it in a particular place, the community retains an element of control in making the decision and there can be some success," said Egon Frech, coordinator of public and government affairs for waste management for Atomic Energy of Canada Ltd., Pinawa, Man.

A low-level solution

While high-level disposal problems will persist beyond the turn of the century, more progress has been made in getting rid of the low-level type. The volume of these wastes—more than 100 times that of high-level materials—can often be reduced by compaction, shredding, and incineration. Because the radioactivity involved is small, low-level wastes rarely require radiation shielding. On the intermediate level, reactor resins, solidified chemical sludges, or used equipment are radioactive enough to need shielding during handling, as noted earlier. More problematic are mixed wastes, which contain both radioactive and other hazardous materials, such as organic chemicals, which makes safe disposal difficult.

Some countries, like Japan, store low-level wastes at the reactor site. But many others already have many years' experience with building structures that will keep the wastes from contaminating groundwater for the few hundred years they pose a threat. In fact, some of the early low-level sites are almost full. And in some countries, officials and public-interest groups insist that the waste problem be solved before any new reactor construction can begin.

What to do about waste may now be more of a social than a technical problem. Organizations that have managed the back-end of the nuclear fuel cycle have followed a conventional policymaking pattern. Officials tended to put off thinking about what to do with the slowly rising volumes of wastes generated while the nuclear industry was getting started during the 1950s. Writing about the policy-making process in a 1985 Office of Technology Assessment report, Daniel Metlay, of Indiana University in Bloomington, pointed to the early lack of concern over the waste issue evinced by officials of the Atomic Energy Commission (it was disbanded in 1975, its functions being absorbed by the DOE and a new agency, the Nuclear Regulatory Commission).

"In the history of the AEC," said Metlay, "there was only one Commissioner, Clarence Larson, who took a major interest in waste management. But even he never championed the area's needs in the same manner that James Ramney pushed reactor development or Glenn Seaborg pushed physical research. For most of the Commissioners, waste was unpleasant, unglamorous, and low priority."

Postponing decisions for so many years has given waste management a prominent public profile today. Recently national and international public-education programs have been growing rapidly. The IAEA is compiling a source book of waste management and disposal issues, giving an overview of how countries deal with wastes, communicate with the public, and imple-

ment policies. But still greater efforts may be needed. "It is evident that this educational effort may be more difficult than the engineering effort that has been required," IAEA director Hans Blix has said.

SPECIAL REPORT: PART 2

Learning from nature

Promising technologies have been demonstrated, but gaining public support is another matter

From a technical standpoint, the management of high-level nuclear waste devolves to one critical task: isolating the material so thoroughly and for so long that hardly any radionuclides ever seep into groundwater and thence into the food chain. Remarkably, nature itself showed how such wastes might be isolated two billion years ago in Gabon, Western Africa.

In 1972, geologists discovered evidence of a natural nuclear chain reaction that occurred there for a few hundred thousand years in a deposit of uranium ore. When the reaction finally ended, the radioactive byproducts were left sealed and isolated within the surrounding ore for millions of years. This event intrigued researchers in Europe, the United States, the Soviet Union, and India, who had for years been trying, in effect, to do the same thing, using glass and steel canisters instead of natural ore. The process is called vitrification.

The success of vitrification in keeping radioisotopes from leaching into the environment is linked to two properties of glass: its relatively impervious nature, and its flexible interatomic structure, which easily surrounds and accommodates wastes and radioisotopes of any shape, surface, or atomic size.

The French have made the most progress. Since 1978 they have vitrified high-level wastes at a pilot industrial-scale plant in Marcoule, France. A large-scale vitrification plant has been in operation at Cap La Hague since November 1989; it handles up to 800 metric tons of spent fuel per year. British Nuclear Fuels PLC plans to implement the French process, called AVM (for Atelier de Vitrification Marcoule), in its Windscale vitrification plant, now nearing completion as part of the giant Thermal Oxide Reprocessing Plant (Thorp) at Sellafield in Cumbria.

Under a cooperative program with West Germany, a competing vitrification technique has been developed in Belgium, where a pilot vitrification plant has been operating since 1985.

At Marcoule, liquid high-level wastes are prepared for vitrification by mixing them with calcining additives and feeding the mixture into a rotating kiln. The dried, oxidized output from the kiln is mixed with frit (partly fused sand and vitreous substances—the raw material of glass) and that mixture falls into a 1150° C furnace that melts the glass. The mixture of molten glass and waste is poured directly into stainless steel storage canisters, each 1.3 meters high and holding about 360 kilograms, which are then welded shut and decontaminated on the outside.

Another French vitrification plant is now entering full operation at Cap La Hague in Normandy; this process is called AVH (Atelier de Vitrification de la Hague), an improvement on the standard AVM technique.

In the German-Belgian process, called Pamela, electrodes are used in a smelter-like arrangement to produce molten glass, into which the waste is dropped. And in Japan, yet another pilot vitrification plant, at Tokai, is scheduled to begin operation this year.

The United States has vitrification plants under construction, based on the German-Belgian process, at West Valley, N.Y., and at Savannah River, S.C., for operation as of 1992. The $920 million Savannah River plant will be the largest in the world and will take about 15 years to vitrify the 130 000 cubic meters of high-level waste now stored there. The U.S. process differs from the French and Belgian methods in that it works with the thick sludge that contains most of the radioisotopes in the tanks of military high-level waste.

A third U.S. vitrification plant is planned for construction at Hanford, Wash., the world's oldest plutonium production facility and the site of some 250 000 m^3 of liquid high-level waste. Plans call for the Hanford plant to be operational in 1998.

France, UK lead

Liquid high-level waste is created, as mentioned above, when commercial or military fuel rods are reprocessed to recover isotopes of plutonium and/or uranium for reuse in reactors [see "Nuclear wastes: the challenge is global," p. 18]. France has two reprocessing sites, both run by Compagnie Générale des Matières Nucléaires (Cogéma), the state-owned reprocessing and waste-handling concern. The one at Marcoule can handle up to 450 metric tons per year. The other, in Normandy, is designated UP2 and can reprocess 400 tons per year, but is being expanded to double that capacity. Meanwhile, a second (800-ton-per-year) facility, UP3, recently began reprocessing fuels from light-water reactors.

Britain's reprocessing site is at Sellafield, on the English coast across from Northern Ireland. The main plant, designated B205, can reprocess an annual 1000–1200 metric tons of magnesium-clad, uranium metal-oxide (magnox) fuels, which are used in the gas/graphite reactors that predominate in the United Kingdom. The B205 plant also reprocesses fuel from British military reactors. A second facility is being built, at a cost of $3 billion, to handle fuels from light-water and advanced gas-cooled reactors. This Thorp is scheduled for completion in 1992 with a planned capacity of 1200 tons a year.

India, which is vigorously pursuing nuclear power, has operated a small (30-ton-per-year) reprocessing facility at Trombay, near Bombay, since 1962. Another plant, with a capacity of about 100 tons a year, is in operation at Tarapur, somewhat farther from Bombay, and a second is scheduled for 1992 operation at Kalpakkam, some distance from Madras.

Japan's nuclear industry relies heavily on British and French facilities for reprocessing, spending an estimated $3.75 billion each year for the British services alone. The country had hoped to ship the plutonium by jet, but officials of the Nuclear Regulatory Agency in the United States, where the fuel originated, refused to cooperate with or sanction the idea. The recently adopted contingency plan, to use cargo ships that would make 27 000-kilometer, seven-week voyages, has provoked alarmed criticism in both Japan and the United States that terrorists might attack a ship and seize or disperse the plutonium. The fissionable materials, mainly plutonium, extracted from the Japanese spent fuel are now being stored at Sellafield and Cap La Hague for shipment back to Japan beginning as soon as 1992.

Japan also has a small (35-ton-per-year) reprocessing facility at the Tokai nuclear installation just north of Tokyo. A much larger (800-ton-per-year) reprocessing plant is now under construction near Rokkasho in northernmost Honshu, the main island.

In the United States, reprocessing of military nuclear fuels is carried out at Hanford, Wash.; Savannah River, S.C.; and Idaho Falls, Idaho. Three commercial reprocessing facilities were also built, in Barnwell, S.C.; Morris, Ill.; and West Valley, N.Y. The Barnwell and Morris plants were never operated, and the West Valley plant was closed in 1972, after six years of operation, amid concern over the levels of radioactive effluents from the plant and plant workers' exposure to them.

More than 2000 cubic meters of liquid high-level waste are still stored at West Valley, where the vitrification plant under construction is scheduled to go on-line late in 1992.

How reprocessing works

The fundamental steps of reprocessing are similar everywhere, mainly because nearly all systems now in use are derived from methods developed in the 1950s and 1960s at Savannah River, S.C., and other Government sites in the United States. The fuel is dissolved and the resulting solution is typically conditioned in a succession of nitric-acid baths. Then the uranium and plutonium are extracted using a solution of tri-n-butyl phosphate and kerosene.

This is the point when most of the high-level waste is produced. The solution that remains after the plutonium and uranium are gone contains most of the isotopes of concern. There are many dozens of them, all relatively long-lived. The solution, mostly nitric acid containing the liquid high-level waste and about 98 percent of the total radioactivity, is diverted to stainless steel tanks fitted with cooling mechanisms such as coils. A second extraction cycle produces intermediate-level liquid waste. Other chemical processes then separate and purify the uranium and plutonium, which are finally recovered as oxides.

The cooling systems play a mundane but critical role: the failure of such a system in 1957 at a Soviet waste storage site in the southern Urals led to the worst waste-related disaster on record. Heat built up in the liquid wastes until a chemical explosion ruptured the concrete container's seal, spewing some two million curies of radioactivity (about 4 percent that of the Chernobyl accident) and contaminating some 15 000 square kilometers. No deaths were caused by the disaster, Soviet officials have said.

In Great Britain and France, liquid high-level wastes are slowly evaporated in a controlled way. In the United States, to inhibit corrosion of the steel tanks that hold high-level waste, the acidic solution has at times been neutralized with sodium hydroxide, creating a thick sludge that contains most of the radioactivity and that settles to the bottom of the tanks.

However, some corrosion and hence a number of leaks have occurred at Hanford and Savannah River since 1956. At Sellafield, low-level discharges into the Irish Sea reached a peak in the 1970s, and have been reduced by an overhaul of the plant's treatment facilities. So far, evidence of radioactive contamination of groundwater has been found at several sites, including Savannah River. All such incidents, wherever they occur, have seriously eroded public confidence, if only temporarily, in programs for handling high-level waste.

High-level searching

Public backing is essential for addressing high-level waste disposal. Because this material may need to be isolated from the environment for tens of thousands of years, it has been difficult to get a consensus from the various regulatory, technical, legislative, and public-interest groups involved in making very long-term policy decisions.

As a result, there has yet to be built a permanent repository for high-level wastes anywhere in the world. Options considered include letting hot waste canisters sink below the polar ice caps (rejected because no one knew what would happen to the containers), or even rocketing the waste into outer space (discarded because an accident might happen during transport).

National programs are under way to find suitable geologic sites in formations of: clay (Belgium, France, Italy, Switzerland, and the UK); crystalline rock (Canada, Finland, France, Japan, Sweden, Switzerland, the UK, and the United States); salt/anhydrite (West Germany, France, Netherlands, Switzerland, the UK, and the United States); and volcanic ash, or tuff (Japan and the United States).

Several national governments have established their own underground laboratories to study questions such as the minimum acceptable depth, the speed of waste canister corrosion, and the hydrological behavior of the type of backfill used to seal the repository. There have also been attempts to mount regional or even international research efforts.

Perhaps most notable is Sweden's Stripa project, sponsored by the Organisation for European Cooperation and Development's (OECD's) Nuclear Energy Agency. Begun in 1980, radar, seismic and hydraulic measurements are testing groundwater flow in the abandoned Stripa iron-ore mine in central Sweden.

Natural analogues

Confidence that radioactive materials will move only limited distances from a repository stems from investigations of so-called natural analogues. These are formations of rock where natural radioactivity has left a record of its decay over the millennia—the Gabon site, discovered in 1972, being one of the most striking.

Another example was found in northeastern Saskatchewan, where researchers at the Cigar Lake uranium deposit are trying to determine why radionuclides have not moved, despite having been saturated with groundwater for millions of years. A similar project was started in 1981 by five OECD nations, which are studying uranium ore deposits in the Alligator Rivers region in Australia's Northern Territory.

Any final repository will not rely solely on the physical characteristics of the rock, but, instead, on the concept of "defense in depth"—both natural and engineered barriers. In addition to vitrifying the wastes and burying them in a stable formation, they will be placed in metal containers and backfilled with the rock from which the repository was excavated.

Nevada objects

The engineering travails of actually choosing and excavating a site are apparent in the Waste Isolation Pilot Plant (WIPP), near Carlsbad, N.M. The site is intended as a repository for transuranic wastes—those with alpha activity exceeding 3700 becquerels per gram. Early investigative work on WIPP began in the mid-1970s in the Los Medanos area of New Mexico. Drilled 650 meters down into a vast salt formation—salt tends to seal water seepage—it is supposed to hold more than a million 208-liter barrels. Although the project has gained some local support for the 500 jobs it will bring to the area over a 25-to-30-year period, it triggered opposition two years ago when water was found to be leaking into the facility—and later when the ceiling and floors in storage rooms started to crack. Waste disposal operations have therefore yet to begin.

Delays have meant that DOE and the Pentagon last year had to begin searching for a military base to temporarily store plutonium wastes from the Rocky Flats, Colo., nuclear weapons plant. Off-site storage was needed because the plant was approaching the transuranic-waste limit of 1.1 million liters agreed upon by DOE and the state of Colorado, whereupon storage at the site would cease. Governors from several states immediately voiced their opposition to giving a home to the orphaned wastes.

Even more controversy has arisen from a plan to store high-level wastes from both the civilian and defense nuclear programs in the Nevada desert 100 miles northwest of Las Vegas. The Yucca Mountain repository is supposed to be embedded 300 meters below the surface in tuff. The site is located in the unsaturated zone, above the water table, where there is scant rainwater—less than 150 millimeters a year.

The state of Nevada has opposed the project since the U.S. Congress canceled a competitive site-selection process in 1987 and designated Yucca Mountain as the only site to be investigated. The state government has refused to grant the necessary environmental permits for site exploration, prompting the DOE to file suit in January to get the state to act on the department's request. While a high-level repository was originally scheduled to begin operation by 1998, the delays have meant that no site will open until at least 2010, if at all.

While the search for a long-term repository continues, dispos-

(Continued on p. 48)

Telephone challenges: a plethora of services

Mickey Mouse phones join that old black Western Electric handset as collectors' items—today's telephone products and services let a caller do a lot more than just say 'hello'

The following is the second of a series of articles on technical advances and changes in the regulatory climate in U.S. telephony since the court-ordered divestiture of AT&T Co. six years ago. The first article was published in May.

An electronic peephole lets you know who is calling before you pick up the ringing phone. The push of a few buttons traces an obscene call so the police can be notified. An incoming call turns off your cassette player and, if you choose to answer, replaces the music coming through your headphones with the caller's voice. Several telephone numbers ring with different patterns on every phone in the house, but only one telephone line runs through your walls.

Although all these features may not yet be taken for granted in most households, their use is spreading as consumers learn how their telephones can enhance the way they communicate.

After the Federal Communications Commission (FCC) deregulated customer premises telephone equipment in the late 1970s, a wave of winsome devices hit the consumer shelves. There were Mickey phones and Snoopy phones, $10 telephones that looked like hamburgers or Coke bottles, $200 bronze-plated antique phones, and even duck-shaped phones that quacked.

But those initial changes were primarily cosmetic. Now, a decade later, the many companies that make telephone equipment and provide telephone service offer a lot more.

A Class act

Perhaps the most revolutionary of these new functions is a set of services based on Custom Local Area Signaling Service (Class) technology. Introduced in New Jersey in 1987 (about 75 percent of that state's telephone customers now have access to the technology), Class provides caller identification, call block, priority call, return call, repeat call, select forward, and call trace. Throughout the nation, it is being rolled out at varying clips, depending on state regulatory climates and the pace of technology upgrades in the network. Most states are expected to offer some Class features in at least a few service areas by the end of 1991.

Before the development of Class technology, telephone customers already had some call control options. A set of custom calling features, including call waiting, call forwarding, and three-way calling, were introduced into the telephone network some 15 years ago, with software written for the 1ESS (Electronic Switching System No. 1) switch. This technology signals incoming calls even when the phone is in use and can reroute incoming calls. It could not distinguish between incoming calls, because the call origination data was not sent from switch to switch.

Class can make such a distinction by taking advantage of a change in the way calls are routed. In the traditional architecture of the telephone network, the signaling between switches, including the call-routing information (the digits dialed), preceded the voice signal over the same set of lines: rapid tones were heard as the information was passed along. Although AT&T introduced a way of separating call- routing information from voice signals in the 1970s, this early technology was not economical for use in local central offices.

In 1984, though, a new standard was developed: Common Channel Signaling System 7 (SS7). With SS7, the call-routing information precedes the voice signal until it reaches the local switch where it is split off into a separate 56-kilobit-per-second signaling network. This separate data network allows much more information to be passed among the switches, including the calling number as well as the routing instructions.

Within three years, local operating companies and long-distance carriers began installing SS7-based hardware at their switches. Today, 40 percent of the U.S. telephone network uses SS7, and almost 100 percent is expected to use it by 1994. Only the caller identification option among the Class services requires special equipment on the customer's end. With caller ID, the destination switch stores the originating number, the date, and the time, sends a ring signal to the call recipient's phone, followed by a burst of data that indicates the originating number, and then sends a second ring. A caller ID device containing a modem is triggered by the first ring to accept the data burst. Within a second or so, software decodes the data and the originating call's number is displayed.

For all other Class options, the data from the most recent call received is stored in memory at the switch. The recipient picks up the phone and dials a code (* plus two digits) to activate a return call, a call trace, or any of the other Class services. But these codes are not the best user interface, service providers and equipment manufacturers agree, and they are testing various menu interfaces that could replace them.

Future telephones are expected to be introduced that have buttons labeled, for example, "Return Call," so that pushing a single button will send the codes to activate Class features. A caller ID telephone from Northern Telecom Ltd., Toronto, already has some extra buttons that can be preprogrammed by the operating company offering the service [see photo, p. 26]. Meantime, savvy users will dedicate a few of the buttons on their programmable phones to the Class functions.

Both AT&T Co. and Northern Telecom provide the Class and SS7 software. Another version of the software is being developed by Siemens AG, Munich. Class can also be used at a switch that is not on an SS7 route, but it functions then with local calls only.

Currently, although Class features are implemented by Class software installed in the switches, some operating companies are not sure that switch-based software is the best way to implement Class-like features. For one, Ameritech Corp. in Chicago, which has implemented some Class services, has announced its plan to begin installing Advanced Intelligent Network (AIN) components in 1991. Another, U S West Advanced Technologies Inc., En-

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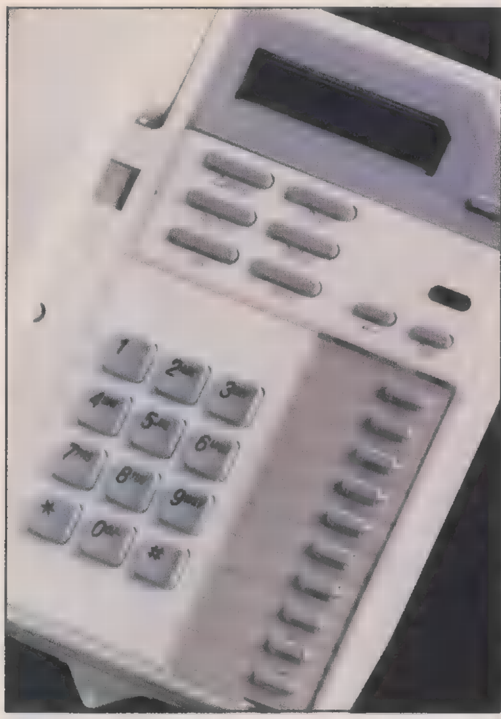
Maestro, the first residential telephone designed to take advantage of caller identification services, displays the origination number of incoming calls on its liquid crystal screen. Buttons can be programmed to use other new services, such as automatically returning the most recent call received. Maestro, made by Northern Telecom Ltd., is sold by local telephone operating companies for $120 to $136.



Northern Telecom Ltd.

glewood, Colo., is currently testing Class software, but is also considering AIN as an alternative. Said Joseph Wetzel, technical director for U S West: "If you want to modify the way a Class feature works, you have to go back to your three or four switch manufacturers and request changes in the software, which may take years."

The AIN, being developed through Bell Communications Research Inc. (Bellcore), Livingston, N.J., puts the control software in a computer outside the switch, Wetzel told *IEEE Spectrum*, so that computers more powerful than switch hardware can manipulate a call. This system could implement Class features, as well as many others. For example, software might replace the dial tone (now automatic on the lifting of a receiver) with access to menus of functions or to a home intercom.

Class services are expected to evolve rapidly. Through market research, some operating companies have discovered that telephone customers are interested in call-waiting ID, which displays a second incoming call number while the telephone is in use. Telephone hardware that can detect the off-hook signaling of call waiting as well as the on-hook signaling of today's caller ID is being developed.

Some operating companies and telephone vendors, through research, have learned that caller identification by name instead of by number is preferred by many consumers. To implement name identification, the originating number data has to be routed to a database that matches numbers with names, or subscriber names would have to be stored at the switch. The name is then fed back into the network as a digital code, decoded, and displayed by a special caller-ID telephone. (Northern Telecom expects to introduce a name identification telephone next year.)

Name instead of number identification might also lull the current privacy debate. Caller ID is viewed by some as an enhancement of personal privacy—an electronic peephole that allows the receiver to see who is calling before answering the phone, much as people might be requested to identify themselves before gaining entry into a home. However, others fear that people who pay to keep their numbers unlisted will lose their confidentiality and that caller ID would inhibit anonymous callers to crisis hot lines.

The American Civil Liberties Union, based in New York City, is contending that caller ID violates the Electronic Communications Privacy Act, a Federal law prohibiting the unauthorized use of devices that trace incoming calls. A bill introduced in the U.S. Senate and House this year, called the Telephone Privacy Act of 1990, would require the operating companies to offer callers a way to block the transmission of their numbers at no charge. The California state legislature already has passed such a bill, and legislators in other states have begun discussing the issue. Pacific Bell, San Francisco, has delayed introduction of Class services until modifications are made to allow blocking.

But even a blocking option may not clear the path for caller ID. Bell Telephone of Pennsylvania had received approval from that state's Public Utilities Commission to offer the service, but in May a state appellate court ruled that caller ID, even with blocking, violates Pennsylvania's wiretap law. That ruling is expected to be appealed.

Meanwhile, by packing today's telephones with microprocessors and memory, manufacturers are able to offer consumers a wide selection of services that do not require any intervention by network operators. Multiple programmable buttons allow users to input dozens of frequently called numbers, easily activate speakerphones and two-way conversation recorders, silence the user's end of the conversation, and repeatedly redial a busy number. And while such telephones may be high-priced, with feature-laden phones costing several hundreds of dollars, they free the consumer from monthly add-on service charges.

Cutting the cord

This year, for the first time, more telephone purchasers are expected to reach for cordless phones than for corded ones. Cordless phones, first introduced in the early 1980s, are convenient because they can be carried easily at a whim throughout the house and yard. But only in the past few years has the quality of a call on a cordless phone approached that of corded phones.

Lack of sound quality was only one of numerous problems of the first generation of cordless telephones. Another was interference. The FCC initially allocated five pairs of channels for cordless telephone transmission, but as cordless telephones proliferated, the odds of two neighbors transmitting on the same frequency increased. With this spectrum allocation, the base transmitted to the handset at frequencies of around 1.7 megahertz; the handsets transmitted at frequencies of around 49 kilohertz. Since the frequencies in the pairs were so far apart, users with a clear signal were unaware that the person on the other end may have been struggling to hear over interference.

Also, many of the telephones produced were simply badly designed, said Richard Frenkiel, department head for consumer products at AT&T Bell Laboratories in Holmdel, N.J. Some would ring when they weren't supposed to. To save money, some manufacturers put the ringing signal through the earpiece, which could hurt eardrums. The cordless industry lost many customers because of these problems, said Jon Hulak, an analyst for Personal Technology Research in Cambridge, Mass.

Then in 1984, the FCC changed the frequency allocation for cordless telephones to 10 pairs of frequencies at 49 kHz and 46 kHz. Later that year, telephone manufacturers began taking advantage of the new frequencies to win customers back. But first they dumped older cordless phones on the market at low prices, possibly disillusioning even more consumers.

Today's cordless phones, which are microprocessor based, include noise reduction filters to eliminate static. To remove the false ring problem, the bases and handsets communicate digitally, instead of with 6-kHz analog signals. The digital messaging includes a security system that randomly selects one of hundreds or thousands of codes whenever the handset is picked up. These security codes eliminate the problem of someone driving by and dialing a call through a telephone in a house being passed.

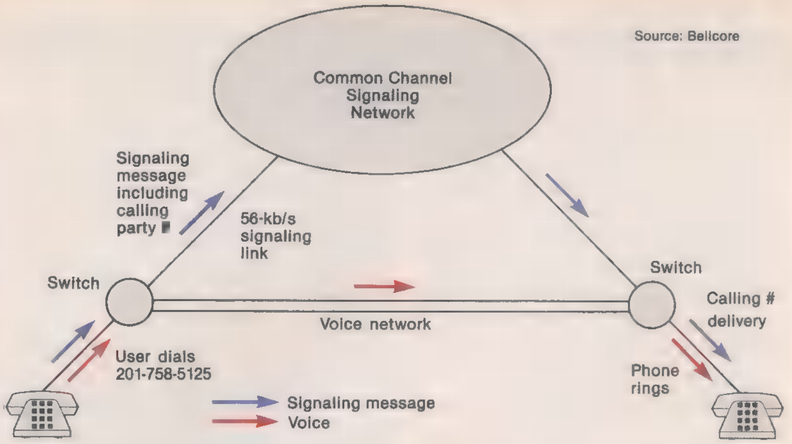
Many of these second-generation cordless phones sold in 1989 and 1990 are not preset on a channel. Rather, the caller selects one of the 10 channels—whichever is clearest—each time a call is made, and he can change channels during the call. Some of the top-of-the-line models scan the 10 channels automatically.

But cordless phones may get some competition from a surpris-

New telephone services

Service	Technology (in network)	Rate	Vendors[1]	Customer premises equipment	Cost	Vendors[2]
Caller ID	Customer Local Area Signaling Service (Class) Signaling System 7 (SS7)	$6.50–$7.50/month	Nynex, Bell Atlantic BellSouth	Display phone Add-on display device	$120–$136 $40–$80	Northern Telecom AT&T, Northern Telecom
Call block (stops calls from selected numbers)	Class, SS7	$3–$5.50/month or $0.50/day active	Bell Atlantic, BellSouth, SW Bell,[3] Ameritech	Rotary or Touch-tone phone	Varies	Various
Return call (calls back last incoming call)	Class, SS7	$2–$4/month or $0.25/use	Nynex, Bell Atlantic, BellSouth, SW Bell, Ameritech			
Repeat call (redials busy number until answer or preset time limit)	Class, SS7	$1.75–$4/month or $0.25/use	Nynex, Bell Atlantic, BellSouth, SW Bell, Ameritech			
Select forward	Class, SS7	$2–$4/month or $0.50/use	Bell Atlantic, BellSouth, SW Bell			
Call trace	Class, SS7	$4/month or $1–$3/use	Nynex, Bell Atlantic, BellSouth, SW Bell			
Priority call (identifies selected callers with special ring)	Class, SS7	$2.75–$5.50/month or $0.50/day	Bell Atlantic, BellSouth, SW Bell, Ameritech			
Access to computer information services	Computer in network with gateway software	$3/hour or $0.05/minute, plus fee for data service	Nynex, Bell Atlantic, BellSouth, U S West			
Voicemail	Computer in network with voicemail software and hard-disk storage	$5–$6.45/month	Nynex, Bell Atlantic, BellSouth, Ameritech, U S West, Pacific Bell	Touch-tone phone	Varies	Various
Distinctive ringing (one line)	Software at switch, multiple numbers assigned to single customer line	$4–$6/month, depending on number of rings	Nynex, Bell Atlantic, BellSouth, SW Bell, Ameritech	Telephone with standard ringer	Varies	Various
Distinctive ringing (two lines)				Two-line phone	$70–$250	AT&T, Code-A-Phone, Panasonic, Northern Telecom
Feature phone				Programmable push-button phone (includes mute hold, automatic redial, one-touch dialing, speaker-phone, and/or home intercom)	$50–$300	AT&T, Code-A-Phone, Panasonic, Northern Telecom
Cordless telephone				Cordless telephone	$75–$250	AT&T, Code-A-Phone, Panasonic, Phonemate, Sony
Videophone				Videophone	$400	Mitsubishi Electric Sales America, Sanyo
Fax transmission, reception				Home facsimile machine	$300–$1700	AT&T, Canon, Panasonic, Xerox
Fax/phone/answering-device line sharing				Fax/phone switcher	$200	Command Communications, Lynx Automation
Aids for the disabled				Voice synthesizers, enlarged numbers, breath-controlled phones, devices for the deaf	$0–$600	AT&T, IBM

1 Available in limited service areas only. 2 List not comprehensive. 3 SW Bell = Southwestern Bell.



To identify the caller to the party being called, Custom Local Area Signaling Service (Class) technology takes advantage of the Common Channel Signaling Network, which separates call-routing information, including the calling number as well as the number being called, from the voice signal.

ing source. Sales of cellular telephones are booming; some 870 000 were sold in 1989, up from the 300 000 two years earlier, according to estimates by the Electronic Industries Association of Washington, D.C. Currently, most are used by businesses.

Although today's cellular telephone systems act [redacted] additions to, rather than integral parts of, the telephone network, that situation may soon change. The FCC in May authorized testing of microwave frequency (as compared with today's radio frequency) cellular systems, and experimental services are expected to begin within two years. The microwave system's high-frequency telephones use low-power transmitters, so two callers in the same building can [redacted] one frequency without interference. The transmitters and the telephones themselves could also be shrunk dramatically. With such advantages, these "personal communications networks" could replace cordless telephones.

Also booming in popularity is the facsimile machine. Three years ago, all fax models cost well over $2000 and therefore were rarely purchased for use outside the office. Today, the average fax costs less than $1000, and models are available for as little [redacted] $300. Such low prices, along with improvements in transmission speed, quality, and user friendliness, have turned them into [redacted] popular consumer product, useful for sending copies of a child's fingerpaint art as well as work documents.

Please, Mr. Postman

Voicemail, becoming ubiquitous in the office environment, is now available for the home, replacing the home answering machine with [redacted] computerized answering service. On [redacted] standard pushbutton telephone, users dial a code to store a personalized greeting; they dial another code to retrieve messages from the voicemail computer located at the central telephone office or other site.

Voicemail has several advantages over answering machines: it can take messages when people [redacted] on another call, retrieve messages from any telephone, and allow family members who share a telephone line to have separate voice mailboxes. When the receiver is picked up, the dial tone flutters to alert the user that a message is waiting. It also allows the sending of mass "mailings." For example, one phone call can alert members about a meeting.

The technology is nothing new. Implementing voicemail merely requires adding software, hard-disk storage, and, in some cases, additional microprocessors to the switches in the central office; it does not require that central offices be upgraded to SS7. (Some voicemail hardware does not have to tie directly into the switch, tying into the network at [redacted] remote facility instead.)

A voice-message storage system was tested by AT&T prior to divestiture, but was never implemented in the network because it was included in the ruling prohibiting Bell operating companies from entering the information services business. That ban was lifted on March 7, 1988.

This call's for you

Voicemail separates calls for different individuals in [redacted] residence only if no one picks up the phone. Then, [redacted] prerecorded voice message directs the caller, for example, to "Press 1 for John, press 2 for Mary, press 3 for Suzie."

Other telephone services target calls with distinctive rings. Each member of the household is assigned [redacted] different telephone number, even though only one line connects the house to the telephone network. Through software at the local switch, calls for the different numbers trigger different ringing patterns. So calls for John may sound as "Riiinng, Riinng," Mary's calls chime "Ring ring, Ring ring," and Suzie's calls come in as "Ring riiing ring, Ring riinng ring." These patterns also sound as call-waiting tones.

This distinctive ringing feature will not work with telephones whose ringers [redacted] not controlled through the telephone lines. Such phones use the burst of current to switch on patterns of sounds as, for example, telephones shaped like ducks that quack.

Number, please?

Some callers dialing O may find themselves talking to [redacted] computer instead of a human operator. This Automated Alternate Billing Service (AABS) was developed by Northern Telecom's R&D arm, Bell-Northern Research Ltd. in Montreal, Ottawa, and Research Triangle Park, N.C. The system runs on a minicomputer connected to the switch, which incorporates [redacted] 68020 microprocessor and a 350-megabyte Winchester disk drive, along with specialized voice recognition software.

A caller dials O plus the number he is trying to reach. If he responds to the "bong" tone by dialing O again or doing nothing instead of punching out [redacted] credit card number, he will be told to enter 1-1 for a collect call or another telephone number for [redacted] third-party-billed call. The caller is then asked to state his name, which is recorded. The system then connects to the called number, states that a collect call is being made from "John Smith" (the recorded name), and listens for a "yes" before completing the call. Proprietary speech recognition algorithms compare the "yes" or "no" response to [redacted] voice template made from a collection of several hundred thousand voices, [redacted] database, which is still being updated. It is currently in use by Ameritech, BellSouth, based in Atlanta, and Nynex, based in New York City.

U.S. Sprint, based in Kansas City, Mo., has announced [redacted] voice-activated calling card and speed dial system. From anywhere in the United States, Sprint customers can call [redacted] 800-network, state their password, and command "Call home" or "Call office." The number is automatically dialed and billed to their Sprint account. New York Telephone Co. is testing a similar system.

To probe further

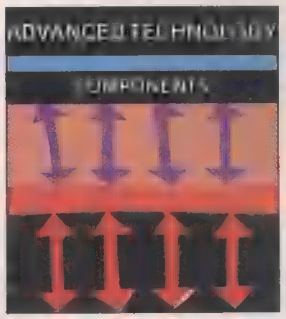
For detailed information about Class technology, [redacted] *Telephony* magazine, 1989 and 1990. Contact its publisher at 55 East Jackson Blvd., Chicago, Ill. 60604; 312-922-2435.

The latest telephones, answering machines, fax devices, and other consumer communications products are demonstrated twice annually at the International Consumer Electronics Show, held in Las Vegas in January and in Chicago in June. For more information, contact the Electronic Industries Association; 202-457-8700.

For information or [redacted] demonstration of telephone devices for the disabled, contact the AT&T National Special Needs Center (800-233-1222) or visit New York Telephone's Communications Center for the Disabled, 204 Second Ave., New York City (800-482-9020). ◆

Silicon micromechanics: sensors and actuators on a chip

Remarkable advances in sculpting minute sensors, motors, valves, and pumps from silicon could affect such diverse fields as optical signal processing and magnetic recording technology



A mechanical microworld is emerging from the technology developed for integrated circuits. Already, completely assembled mechanisms and motors fractions of a millimeter in size are being made in laboratories around the world. New products and new capabilities for engineering and scientific investigations dot the horizon.

Surprisingly, these flea-sized mechanical structures might well transform the control of mechanical elephants like automobiles. By the end of this decade, inexpensive yet highly reliable accelerometers and other sensors could revolutionize the design of suspension, braking, and steering systems. These devices are fabricated on silicon substrates using extensions of such IC manufacturing processes as photolithography, thin-film deposition, and chemical and plasma etching. Thus far, the silicon diaphragm pressure sensor has been the main commercial engine, with many uses in the automotive, medical electronics, and process-control industries.

Micromotors and articulated microstructures are more ambitious and might serve as actuators in a range of electromechanical systems. Rapid developments during the past three years by many groups around the world are coalescing into a multidisciplinary research field, described variously as microelectromechanical systems, micromechatronics, microdynamics, and micromechanics. The new field has also spurred basic studies of the physics and chemistry of materials and structures in the micro-scale.

Fabrication techniques

A number of innovative fabrication techniques have recently been developed specifically for micromechanical structures, and they fall into two categories: bulk micromachining and surface micromachining. The first involves sculpting the silicon substrate by means of chemical etchants, and the second, etching layers of thin films deposited upon the substrate.

In the 1950s, it was discovered that alkaline solutions attack different facets, or planes, of the silicon crystal at very different rates. Indeed, one facet can hardly be etched at all. Exposing an area of a silicon wafer with a specific crystal orientation to these solutions creates cavities with precisely angled walls that are aligned with the non-etching crystallographic planes [Fig. 1]. The common microelectronic thin-film materials silicon dioxide or silicon nitride can serve to mask the portions of the wafer that are not to be etched. To further control geometry, microstructure designers can stop the etch either with a layer of silicon heavily doped with boron or by applying a passivating voltage to one side of a p-n junction. A proven high-volume production process, bulk micromachining is routinely used to fabricate microstructures with critical dimensions that are precisely determined by the crystal structure of the silicon wafer, by etch-stop layer thicknesses, or by the lithographic masking pattern.

For making complex structures, the ability to bond silicon wafers is an important adjunct to bulk micromachining. Engineers at NovaSensor, Fremont, Calif., recently applied silicon fusion bonding to fabricate micro silicon pressure sensor chips [Fig. 2]. Developed in the 1960s, this process fuses silicon wafers together at the atomic level—without the need for a "glue" layer or an applied electric field.

Surface micromachining is based on depositing and etching structural and sacrificial films. After deposition of the films, the sacrificial material is etched away, leaving a completely assembled micromechanical structure. This simple concept was first applied in the 1960s at Westinghouse Research Laboratories, Pittsburgh, with metal films. In the early 1980's, researchers at the University of California at Berkeley began using silicon dioxide as the sacrificial material and polycrystalline silicon as the structural material. The films are grown on silicon wafers by chemical vapor deposition (CVD). The process is useful for making a wide range of micromechanical elements, including beams, bearings, and linkages. By depositing additional films after removal of the sacrificial layer, University of Wisconsin-Madison researchers pioneered a method for making sealed cavities.

Surface micromachining allows the clever microstructure

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Defining terms

Bulk micromachining: a process for making microstructures in which a masked silicon wafer is etched in orientation-dependent etching solutions.
Piezoelectric effect: a phenomenon in which certain materials become electrically polarized in response to applied strain or become strained in response to applied voltage.
Piezoresistor: a resistor that changes resistance in response to applied strain.
Proof mass: the reference mass inside an accelerometer, from whose movement the acceleration measurement is derived.
Sacrificial layer: a thin film deposited in the surface micromachining process that is later etched away to release a microstructure.
Silicon fusion bonding: a process for bonding two silicon wafers at the atomic level without applying glue or an electric field.
Structural layer: a layer of material deposited in the surface micromachining process that will become a structural member of a microstructure, in contrast to a sacrificial layer.
Surface micromachining: a process for depositing and etching multiple layers of sacrificial and structural thin films to build complex microstructures.
Tribology: the study of friction, wear, and lubrication in surfaces sliding against each other, as in bearings and gears.

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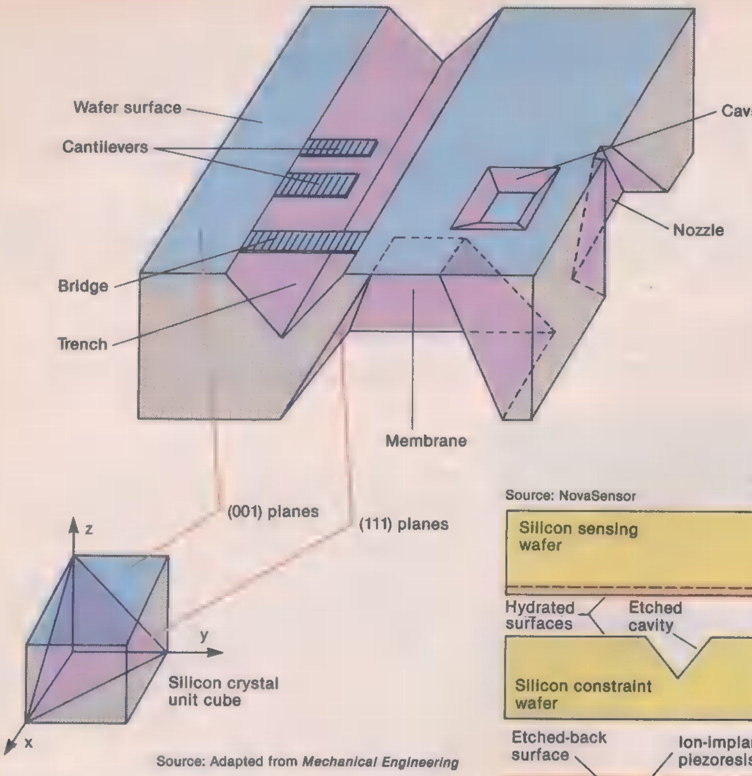
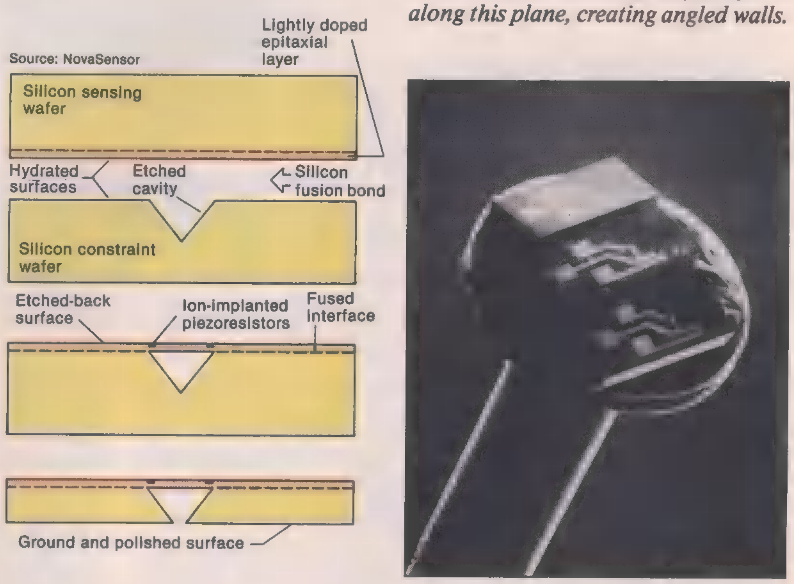


Source: Adapted from *Mechanical Engineering*

[1] Using bulk-silicon micromachining techniques, microstructure designers can sculpt a variety of geometric features in a silicon wafer. (Not all features shown could be etched in one masking step or on the same wafer.) The features at left can be etched in silicon wafers having crystals oriented so that the x-y *plane of the unit cube is parallel to the wafer surface. This plane (in blue at left) is designated by Miller indices as (001), signifying it is perpendicular to a unit vector in the z direction. The (111) plane (in purple) runs diagonally through the crystal's unit cube. Because it etches so slowly, cavity surfaces form along this plane, creating angled walls.*



[2] NovaSensor has applied silicon fusion bonding to fabricating a catheter-tip micropressure sensor. This process bonds silicon wafers at the atomic level without glue or an applied electric field. First, a wedge-shaped cavity bordered by (111) planes is etched in a (001)-oriented silicon wafer (upper middle). The cavity is capped by fusion with another silicon wafer having a lightly doped epitaxial layer (top). A doping-selective silicon etch removes all of the capping wafer except the epitaxial layer, a procedure called etch-back (bottom middle). Using standard IC processes, piezoresistive strain gauges are implanted in the silicon diaphragm and metal interconnections are made. Finally, the cavity is exposed by mechanical lapping of the bottom of the wafer (bottom). The scanning electron micrograph (SEM) on the right shows three completed pressure sensors on the head of an ordinary straight pin.

designer to exploit the uniformity with which CVD films coat irregular surfaces as well as the patterning fidelity of modern plasma etching processes. Multiple depositions of structural and sacrificial films, each individually patterned, can build surprisingly complex micromechanical structures. Still, there is a limit to the number of layers since each one increases surface roughness, gradually degrading the photolithographic process.

Some of the most impressive products of surface micromachining are the electrostatic micromotors fabricated at Berkeley and at the Massachusetts Institute of Technology (MIT) in Cambridge [Fig. 3]. The MIT variable-capacitance motor has a 100-micrometer-diameter rotor and 2-μm-wide air gaps, and has a peak torque of 12 piconewton-meters for an excitation voltage of 100 volts across each opposing air gap. Synchronous motor speeds of up to 2500 revolutions per minute have been observed with 80-V excitation.

MIT recently pioneered the use of polyimide and aluminum as structural and sacrificial layers. Among the advantages of this pairing are that the maximum fabrication temperature is less than 400° C and that structures only 30 μm thick are possible. Because polyimide's cure temperature is so low, these microstructures can be easily combined with prefabricated MOS electronics.

Silicon accelerometers

Several companies are developing silicon accelerometers for active suspensions, anti-skid systems, and air-bag deployment in automobiles. IC Sensors Inc., of Milpitas, Calif., and NovaSensor have products on the market [Fig. 4], and in Japan, NEC Corp. and Hitachi Ltd. have demonstrated prototype devices. These applications require only intermediate performance but very high reliability and low cost. A typical design incorporates a bulk-micromachined silicon mass (called the proof mass) suspended by silicon beams. Ion-implanted piezoresistors on the suspension beams sense the motion of the proof mass produced by acceleration.

Research laboratories are also exploring the utility of silicon accelerometers for high-precision applications such as inertial navigation. In this case, the preferred means for detecting movement of the proof mass is a change in capacitance. In some designs, capacitor plates located on the top and bottom capping wafers (the two wafers that enclose the proof mass) also apply a restoring electrostatic force to the mass to null its displacement, offering improved linearity and dynamic range over "open-loop" devices.

Capacitive accelerometers from Centre Suisse d'Electronique et de Microtechnique SA (CSEM) in Neuchâtel, Switzerland, can detect sub-microgravity accelerations in a 1-hertz bandwidth. Researchers at Messerschmitt-Bölkow-Blohm GmbH (MBB) in Munich have developed a highly symmetrical accelerometer, which is virtually immune to off-axis accelerations. The silicon proof mass is suspended from its corners by eight beams (four each on the top and bottom surface). A switched-capacitor

CMOS application-specific IC (ASIC) measures the variation in capacitance between the proof mass and metal electrodes located in wells etched in the upper and lower glass capping wafers.

The Charles Stark Draper Laboratory Inc., in Cambridge, Mass., recently reported a new approach for capacitive force-balance accelerometers. A torsionally suspended silicon gimbal plate on which metal has been asymmetrically deposited serves as the proof mass and suspension. Acceleration tilts the plate and changes the differential capacitance between the plate and an outer pair of stationary electrodes. Using this signal as input, a control loop generates voltages on an inner pair of electrodes to apply a torque on the plate and null the tilt.

Resonant microsensors

An alternative approach to precision sensing is resonant microstructures. As with a stretched guitar string, a change in tension in a vibrating beam prompts a shift in its resonant frequency that can be conveniently and accurately measured. In a resonant accelerometer from STC Technology Ltd. in Harlow, England, for example, deflection of the proof mass changes the axial load on the resonant microstructure, shifting its frequency. Thermal expansion drives the microstructure's vibration, which is sensed by a diffused piezoresistor. A resonant accelerometer recently reported by General Motors Corp.'s Research Laboratories, Warren, Mich., has a bulk-micromachined proof mass suspended by four polysilicon microbridges, whose vibrations are both driven and sensed capacitively. The difference in resonant frequency in a pair of opposing microbridges is proportional to the component of acceleration aligned with that pair.

A team at Berkeley is investigating a resonant microstructure with potential application in pressure sensors as well as accelerometers. It consists of interdigitated capacitors that excite vibrations parallel to the plane of the substrate [Fig. 5]. The design allows high vibrational amplitudes, in contrast to parallel-plate capacitors in which the amplitude is limited by the gap between the plates. In addition, the folded-beam suspension of the resonator acts as a compliant, linear spring and releases any mechanical stress introduced in the polysilicon film during deposition.

Micromachines

The fabrication techniques developed for microsensors are now being applied to microelectromechanical systems such as motors and pumps. Microdynamics research has progressed rapidly in the last three years—witness attendance at the IEEE Micro Electro Mechanical Systems Workshop, which has been increasing about 70 percent a year since its start in 1987. Potential applications range from optical signal processing and surgical instruments to silicon valves, pumps, and fine-positioning actuators for high-performance disk drives. An intriguing aspect of the field is its multidisciplinary character; it draws on silicon microfabrication, mechanical design, material science, tribology, control theory, metrology, electrostatics, micro-telemanipulation, robotics, and other areas.

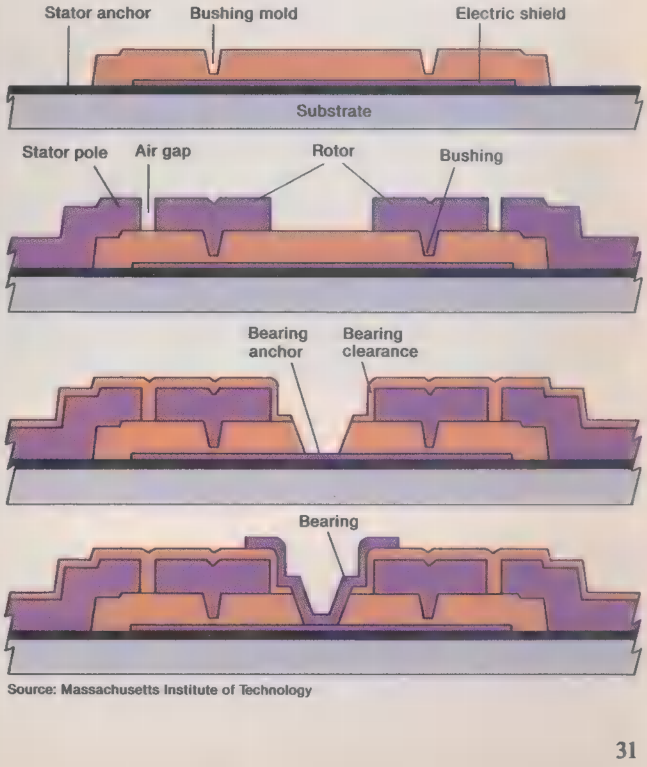
A fundamental issue in microdynamics is the scaling of physical properties into the micro domain. Our intuition and understanding of mechanics has been developed by interacting with the macro world around us. Our ideas of how things behave come from watching automobiles and baseballs, and trying to fix household plumbing. A water bug walking on the surface of a pond, or an ant carrying many times its own weight, indicate that small systems may indeed behave very differently.

Consider a system that is scaled down by a factor of 100. The mass, and hence the inertial and gravitational forces, decrease

(Continued on p. 34)

[3] The variable-capacitance micromotor shown in the SEM exploits the favorable scaling of electrostatic forces in the micro domain. The eight-pronged rotor spins around the center bearing at up to 2500 revolutions per minute in response to voltages applied sequentially to the stator poles encircling it, across a gap of 2 micrometers. The motor has a 100-μm-diameter rotor and was made at the Massachusetts Institute of Technology using the surface micromachining process portrayed below. Polycrystalline silicon is the motor's structural material (in purple), while the phosphosilicate glass serves as the sacrificial layer (in orange), which is etched away after all layers are deposited. After first depositing a layer of polysilicon on a substrate coated with silicon nitride (the stator anchor), a layer of phosphosilicate glass is deposited, and anchor areas and molds for bushings are etched in two masking steps (top). A 2-μm-thick polysilicon layer is then deposited and patterned to form the rotor and stator segments (top middle). To create clearance for the bearing, another sacrificial layer is deposited and patterned (bottom middle), followed by a third polysilicon layer to form the bearing (bottom). The glass is etched away with hydrofluoric acid, releasing the rotor.

Massachusetts Institute of Technology



Source: Massachusetts Institute of Technology

Silicon micromechanics

(Continued from p. 31)

by a factor of 1 000 000. Forces that scale as the area of the system, such as electrostatic attraction, will decrease by a factor of only 10 000. As a result, the ratio of such forces to inertial forces increases by a factor of 100. For example, dust particles on the surface of a mirror are held there by an electrostatic force that is much stronger than the gravitational tug on them.

The forces useful for actuation have a wide range of scaling laws. Electromagnetic forces are dominant in the macroscopic world, but scale as the area squared (assuming constant current density in the actuator windings), and so shrink rapidly as systems become smaller. Increasing the current density with size reduction will result in a more favorable scaling law at the cost of greater power dissipation.

Several forces scale with the area, including pneumatics and electrostatic attraction, assuming a constant electric field. In fact, the breakdown electric field increases in small gaps by a factor of over 10 times the macroscopic limit of 3 megavolts per meter, resulting in an even more favorable scaling for electrostatics. Finally, the forces of surface tension scale with the linear dimension of the system and become large relative to other forces, as the water bug example shows.

As this scaling analysis suggests, electrostatic forces are more suitable than electromagnetic forces in the micro domain. In addition, in contrast to multiturn windings, capacitors with small gaps are fairly easy to fabricate with surface micromachining. Logically enough, therefore, the initial silicon micromotor research efforts at MIT, Berkeley, and AT&T Bell Laboratories in Holmdel, N.J., have focused on electrostatic micromotors of various designs.

The piezoelectric effect also scales with the area, making it an attractive means of actuation. A microfabricated cantilever beam developed at Stanford University for scanning tunneling microscopy moves in three dimensions when voltages are applied to four independently addressable regions of piezoelectric zinc oxide.

Micromachined valves were first demonstrated in the mid-1970s in the Stanford silicon gas chromatograph project. Recently other IC-based valves have been under intensive development at Tohoku University in Sendai, Japan, and the Twente University of Technology in Enschede, the Netherlands. Tohoku researchers have demonstrated a variety of flow-control systems built around one-way valves with suspended polysilicon check rings and fabricated by a combination of bulk and surface micromachining techniques. To control the diaphragm displacement, miniature piezoelectric actuators are mounted on the silicon micromachined wafer.

Thermal expansion can also provide the force for seating valves or displacing diaphragms in microfabricated flow-control actuators. For example, researchers at the University of Twente, extending earlier work at Stanford University, are using the thermal expansion of a gas to actuate a pump.

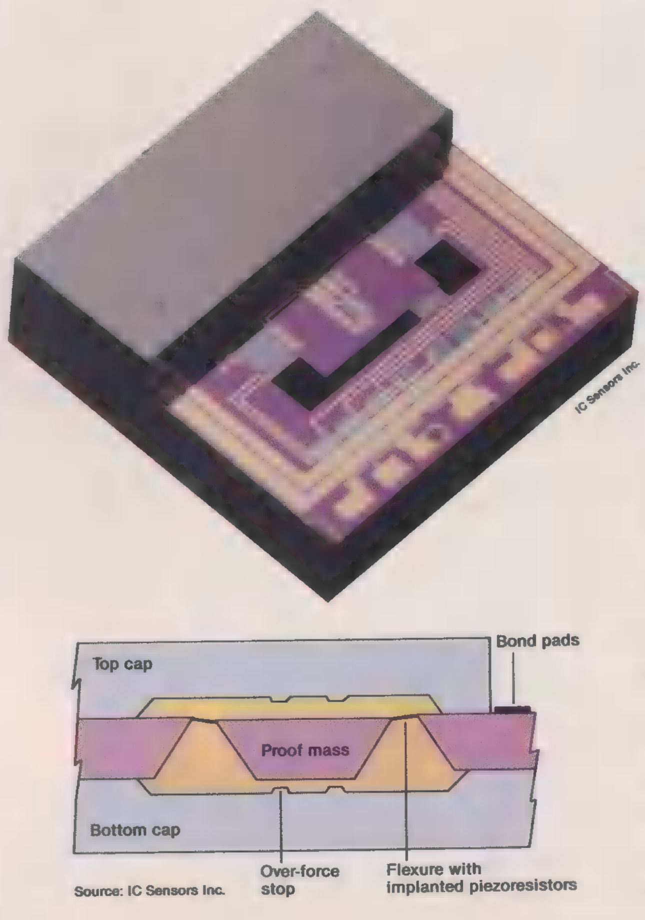
Hitachi Central Research Laboratory in Tokyo is using micromachined silicon components to help cross-breed biological cells. A two-dimensional matrix of 1600 ports etched anisotropically on a 75-mm-diameter wafer serves to position and secure individual cells, one to a port. This carrier plate transports the cells to a 1600-port cell-fusion plate and loads two sets of cells as matched pairs to cell-fusion chambers. The cell pairs fuse when short, high-voltage pulses are applied to them.

Hitachi's automated cell processor has achieved fusion rates of almost 60 percent, as compared to the 2–3 percent fusion rates typical of existing manual techniques. Equally important, the fusion processor also eliminates many unwanted fusion products and the costly and time-consuming separation of fusion products.

From these examples, it is clear that silicon micromachining is a powerful tool for fabricating microdynamic elements. Still, with few exceptions, it is limited either to building thin-film laminated structures or to etching cavities defined by the crystallographic orientation of the silicon wafer. Wafer-to-wafer bonding introduces some additional flexibility into silicon micromachining, at the cost of complicating the process.

A process called LIGA (a German acronym for LIthographie, Galvanoformung, Abformung—in English, lithography, electroforming, molding) could extend the range of batch-fabricated structures to truly three-dimensional structures. Developed at the Fraunhofer Institute for Microstructure Technology in Berlin and the Karlsruhe Nuclear Research Center in Karlsruhe, West Germany, the process fabricates metallic or polymeric microstructures with lateral feature sizes as small as 2–3 μm, yet with heights of more than 100 μm. LIGA builds a mold for creating the microstructures using X-ray lithography and very thick resists, followed by plating with nickel or other metals.

Other nonsilicon micromachining techniques useful for fabricating microelectromechanical systems include molding, plating, single-point diamond machining, and electro-discharge machining (EDM). Harmonic wobble motors, demonstrated at AT&T Bell Laboratories and the University of Utah in Salt Lake City, are a type of electrostatic micromotor made with nonsilicon techniques. Since its rotor rolls inside a stator having a slightly larger bore diameter, it has an inherent gear reduction and reduced friction losses. Utah's fabrication method is to co-extrude stainless steel wires covered with a polyethylene thermoplastic. The resulting insulated stator electrodes attract the rotor and cause it to roll inside the stator. University of Tokyo researchers have made harmonic wobble motors using disks or cones as the rotors.



[4] The cross section of a silicon microaccelerometer developed by IC Sensors Inc. for automotive applications shows the proof mass displaced by a vertical acceleration, which is sensed by piezoresistive strain gauges embedded in the four supporting flexures. The optical micrograph shows the device with the upper capping wafer partially removed, exposing two of the suspension flexures and part of the proof mass.

Nonsilicon processes will also be crucial for physical interconnection of silicon microdynamic chips. Packaging such systems is more challenging than for microelectronics, because the environmental requirements vary widely with each application and often are severe. In addition, the package is called upon to transmit mechanical as well [redacted] electrical signals. Development of flexible, cost-effective packaging technologies will probably pace the introduction of commercial applications.

Materials measurements

Although many of the mechanical properties of crystalline silicon are well documented, the increasing variety of thin-film materials has made measurement of their mechanical properties an important activity. Young's modulus, the ratio of the applied stress to the strain in [redacted] material, along with residual stress, are key parameters in the design and operation of microdynamic devices.

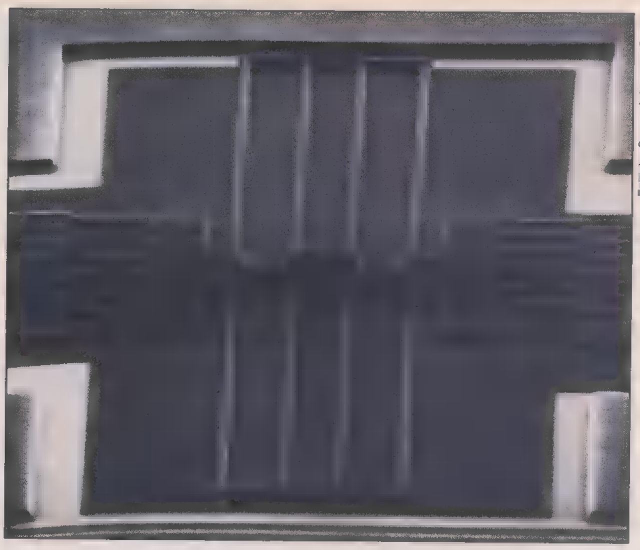
Load-deflection characteristics have been measured in [redacted] number of ways, including applying microprobes to directly deflect tiny silicon cantilever beams. Polyimide, polysilicon, and silicon nitride films have been studied by applying pressure to diaphragms made of the materials. A method developed at MIT circumvents externally applied loads altogether; for films with a tensile residual stress, such as polyimide films, asymmetric structures can be fabricated so that they displace on their own after release from the substrate.

Workers at the University of Michigan in Ann Arbor have devised an inventive measurement technique, in which [redacted] suspended microbridge is collapsed against an underlying electrode by electrostatic forces. The critical voltage at which this occurs, called the pull-in voltage, is conveniently measured by monitoring the capacitance between the microbridge and electrode.

With growing interest in microdynamic structures, measurements of friction and wear are of great importance. AT&T researchers have measured the lifetime of a polysilicon turbine at three minutes when it operates at 300 000 rpm. They ran the device at up to 600 000 rpm by applying an air jet from [redacted] micropipette. These results and studies done at Berkeley and MIT indicate that friction and wear in microbearings are critical problems in the design of microdynamic systems.

Substantial work is under way to control the mechanical properties of microstructural materials. A prime example is work at the University of Wisconsin-Madison on how best to deposit and anneal polysilicon films so as to optimize their mechanical properties. A fine-grained, undoped polysilicon film with reproducible mechanical properties (Young's modulus and residual stress) can be produced by low-pressure CVD at 590° C on thermal oxide. Annealing after deposition can either eliminate stress or, if desired, induce [redacted] moderate tensile strain.

New materials with improved mechanical properties are being investigated for application to both surface- and bulk-micromachined structures. IC Sensors has integrated polycrystalline diamond deposited by plasma-enhanced CVD into a silicon diaphragm fabrication process. Diamond and diamond-like films have a strong appeal for microdynamics because they are hard, chemically inert, and resist wear. In addition, their high thermal conductivity may be of use in microactuators based on thermal expansion. Porous silicon is also under investigation.



[redacted]ley Sensor & Actuator Center

[5] The University of California at Berkeley developed this polysilicon microresonator for potential use in pressure sensors and accelerometers. The resonator is driven parallel to the plane of the substrate by applying voltages to the interdigitated capacitors. The structure is suspended 2 micrometers above the substrate by 200-μm-long folded flexures.

Active films, principally piezoelectrics, have been integrated into silicon microstructures for both sensing and excitation through research over the past decade at Berkeley and the University of Twente. Recently, thin films of shape-memory alloys (Nitinol) have been incorporated into a surface-micromachining process for use in microactuators at AT&T Bell Laboratories.

The field of micromechanics, despite its many advances, is clearly in its infancy. The next decade will be an exciting time as researchers explore the microscopic world and commercial applications begin to emerge.

To probe further

A collection of IEEE papers [redacted] microsensors is due out this month in *Microsensors*, an IEEE reprint volume edited by Richard S. Muller, Roger T. Howe, Stephen D. Senturia, Rosemary L. Smith, and Richard M. White. It is available under catalog number PC 02576 from the IEEE Service Center. Phone: 1-800-678-4333.

Technical publications in silicon micromechanics appear in the *IEEE Transactions [redacted] Electron Devices*, with the special issue in June 1988 being of particular interest. *Sensors and Actuators* (Elsevier: Lausanne, Switzerland) is the specialist journal in this field.

An up-to-date overview of research progress can be found in the technical digests of the IEEE Solid-State Sensor and Actuator Workshop, held in June of even-numbered years since 1984 in Hilton Head Island, S.C., and the IEEE Micro Electro Mechanical Systems Workshop, held in Hyannis, Mass., in November 1987 (as the IEEE Micro Robots and Teleoperators Workshop); Salt Lake City, Utah, in February 1989; and Napa Valley, Calif., in February 1990, with the next in the series to be held in Nara, Japan, in late January 1991. A series of International Conferences on Solid-State Sensors and Actuators has been held in June of odd-numbered years since 1981, with the most recent one held in Montreux, Switzerland (Transducers '89). The next in the series will be Transducers '91, to be held in San Francisco. Contact Linda Reid or Karen Anderson at the University of California at Berkeley; 415-642-4152.

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Kaigham J. Gabriel (M) is [redacted] visiting associate professor at the Institute of Industrial Science, University of Tokyo, on leave of absence from AT&T Bell Laboratories, Holmdel, N. J. He has an S.M. and Sc.D. in electrical engineering from the Massachusetts Institute of Technology in Cambridge. William S. N. Trimmer (M) is [redacted] member of the technical staff at AT&T Bell Laboratories in Holmdel, N.J., and has [redacted] Ph.D. in physics from Wesleyan University in Middletown, Conn. ◆

Looking over the horizon

Advances in signal processing have made HF radar an operational reality

Like so many other technical ideas, over-the-horizon radar had to wait for the digital era before it could begin to reach its full potential. For about 30 years, this conceptually simple—yet practically very complex—technology was in the research phase, kept alive solely by the desire of a country's military forces to provide the best possible defense of its shores, and also to peek as far as it could beyond the borders of its adversaries.

More recently, however, thanks to the processing power of modern computers and more especially digital signal processing (DSP) chips, over-the-horizon (OTH) radar has become an operational reality. Both the U.S. Navy and the U.S. Air Force have working units in place, with construction proceeding on others. Research and development in the technology is also being pursued in the United Kingdom, Canada, France, Australia, the USSR, and China.

And just [redacted] international tensions seem to be thawing, possibly reducing the need for defense systems, other applications for OTH radar have come to the fore, most notably the interdiction of drug traffickers and the monitoring of wind patterns over vast stretches of the ocean.

Basically, OTH radar is able to see beyond the horizon because it uses the ionosphere to refract its waves back to earth. Where conventional microwave radar frequencies of 200–40 000 megahertz propagate right through the ionosphere, the lower frequencies used in OTH radar (3–30 MHz) interact with it in ways that can be exploited to provide radar coverage at distances of 500–2000 nautical miles (about 100–3500 kilometers).

Of course, as with most technical developments, there are penalties associated with the use of the long wavelengths (10 to 100 meters) of the high-frequency (HF) band. Antennas must be very large, 1000 meters or more in length. Spatial resolution is relatively coarse—on the order of tens of kilometers—compared to tens of meters for microwave radar. And the frequency band is densely occupied by a host of other services, such as short-wave radio.

In addition, because OTH radar effectively looks down on its targets from the ionosphere, [redacted] large-amplitude backscatter echo from the earth (clutter) is produced at the same range as that of the desired targets. Also, because of the constantly changing nature of the ionosphere, the radar operating frequency and waveform must be constantly adapted.

On the other hand, some of these penalties have advantages hidden within them. The ocean backscatter is from water gravity waves with dimensions comparable to those of the radar waves. Hence those water waves can be visualized and studied to provide a sea and surface-wind diagnostic.

Similarly, ships and large aircraft have dimensions that fall into the resonant scattering region. Since those craft are moving, their returns [redacted] be detected by measuring the frequency deviation (Doppler shift) they cause in the reflected wave.

It is also possible that OTH radar may prove to be valuable for detecting stealth aircraft, which were designed to have very small radar cross sections as seen by conventional microwave upward-looking radar. Many radar cross-section reduction techniques are, at least coarsely, frequency dependent. Methods that defeat microwave radar may not be effective at HF. At HF, aircraft radar cross section is much more dependent on gross target dimensions than on detail in shape.

James M. Headrick   Naval Research Laboratory

In the beginning

Although radar is associated with microwaves, the earliest radio echo-location systems were the HF sounders used in the 1920s to measure the height of the ionosphere. The original aircraft detection radars installed by the British in the late 1930s were also located at the high end of the HF band because components were not readily available for shorter wavelengths.

Over-the-horizon radar could be said to date from those early days because, at times, communications experimenters detected earth backscatter via oblique ionospheric paths. Even earlier, in the 1920s, they noticed that if [redacted] series of Morse code dots was transmitted, "backsplash" could sometimes be detected by the receiver—backsplash that had a time delay corresponding to the estimated path length of the waves. By the end of World War II, those observations resulted in several plans to extend the range of radar by using ionospheric refraction.

Generally, those early post-war programs produced less than satisfactory results because they lacked adequate means for detecting targets buried in clutter, always a feature of [redacted] downward-

Defining terms

Backscatter: energy reflected in a direction opposite to that of the incident wave.
Clutter: backscatter from the earth's surface.
Coherent processing: echo integration, filtering, or detection of a received signal using [redacted] coherent local oscillator—that is, one whose phase relationship with respect to the transmitter is fixed.
Matched filter: a receiver filter whose impulse response is the time inverse of the transmitted waveform. Equivalently, the filter's frequency response is the complex conjugate of the transmitted spectrum.
Radar cross section: a measure of the reflective strength of a radar target, usually measured in square meters and defined as 4π times the ratio of the power per unit solid angle reflected by the target to the power per unit area incident upon it.
Skywave: a radio wave propagated towards, and returning from, the ionosphere.
Vertical sounder: a radar-like instrument that determines the effective (virtual) height of the ionosphere by measuring the time required for [redacted] signal to bounce off it and return.

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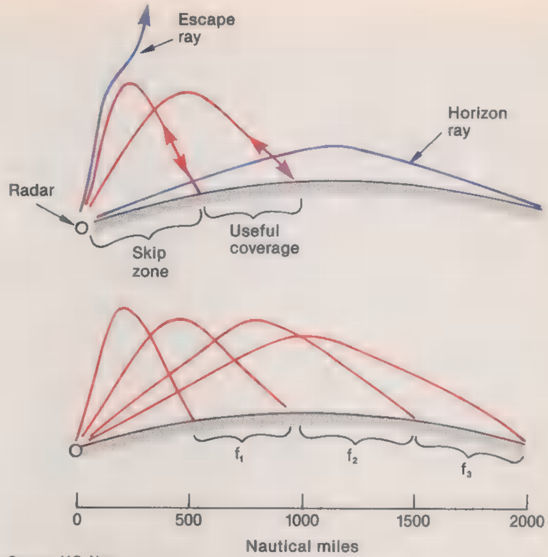
U.S. Navy



Source: U.S. Navy

[1] Over-the-horizon radar range is controlled by varying the launch angle and the frequency of the transmitted beam. The lower sketch shows how three different frequencies, f1, f2, and f3, could be chosen to provide coverage between 500 and 2000 nautical miles. Though exaggerated in the drawing, the launch angles are typically less than 25 degrees and frequently below 5 degrees. The photograph shows the U.S. Navy's Relocatable Over-The-Horizon Radar receiving antenna (above).

looking radar. By the mid-1950s, many were winding down, not least because no accepted threat required such long-range sensors.

At about the same time, interest in the application of new signal-processing techniques and technology to radar was increasing at the U.S. Naval Research Laboratory (NRL) in Washington, D.C. An area of particular promise was the use of matched filters in combination with coherent processing times many seconds in duration. Matched filters had been theoretically shown to offer the best possible signal-to-noise performance, and because coherent processing time is the reciprocal of filter bandwidth, the combination could reasonably be expected to provide Doppler filters with subhertz bandwidths.

Because of the relatively coarse range resolution of HF radar, it is necessary to rely on very fine Doppler filtering to separate targets from one another on the basis of slight differences in their speeds.

The state of technology in the 1950s was such that the HF band was the highest one for which components were available that would permit experimental verification of those new ideas—a situation reminiscent of the reason for early radar frequency selection. More important, HF offered the possibility of increasing detection distance on near-surface targets by orders of magnitude through the use of ionospheric refraction—in other words, it might lead to an OTH radar.

In some modest experiments, HF radar backscatter echoes were examined with a radar having a very stable, low-noise transmitter. Narrowband filter processing of the returns indicated adequate path stability for detection of aircraft amplitude echoes when the target's relative velocity—its velocity component in the direction of propagation of the radar beam—was large enough to allow it to be distinguished from the clutter because of its Doppler shift.

However, the earth-surface echo seen by a skywave path was at a very high amplitude compared with that anticipated from an aircraft target, which meant that challenging dynamic-range problems were to be expected in the receiver and signal processor. Indeed, clutter-to-signal ratios in excess of 60 decibels are common in these systems.

Largely because of the signal-processing problems, the consensus of the radar technical community in the 1950s was against continuing HF radar research. Despite that attitude, and despite many acknowledged and formidable technical difficulties, the early experiments did show that OTH radar in the HF band was feasible.

Therefore, NRL went ahead, designing and building an experimental radar in 1961 that could detect and track aircraft out to ranges of 2000 nmi across the Atlantic. That experimental radar had no digital componentry or processing. It used vacuum tubes and analog components exclusively, and it required real skill to operate.

The main factor behind its success was its proper exploitation of Doppler signal processing. Its analog signal processor components could only handle a dynamic range of 30 dB, which meant that clutter filters had to be used prior to processing, limiting that radar to aircraft detection. (Ships move too slowly for their returns to pass through the clutter filters.)

Other HF radars followed. Among them, they demonstrated most of the capabilities of HF radar by the early 1970s. Those capabilities included ballistic missile launch detection, aircraft and ship detection and tracking, and ocean storm tracking.

Also in the late 1960s and early 1970s, the use of relatively high resolution in both the range and azimuth dimensions and the ability to perform automatic detection and tracking of aircraft and ships were demonstrated by several experimental programs. These were carried out under the sponsorship of the Air Force Systems Command, the Office of Naval Research (ONR), and the Advanced Research Projects Agency (ARPA, now Darpa). Operational radars for aircraft and ship detection and tracking could have been realized then if needed.

Ionospheric variations

A major difference between HF skywave radar and conventional line-of-sight systems is the need to adapt the waveform and frequency of the former to the environment. The ionization of the upper atmosphere due to solar activity is what makes skywave transmission possible. Unsurprisingly, therefore, the electron density is much greater in daylight. In addition, seasonal and long-term (11-year and longer) cycles occur, along with a superimposed random component.

The electron density distribution in the ionosphere is what mainly controls radio wave transmission. When an oblique-incidence wave travels through an electron density gradient that increases with altitude, its path is bent away from the vertical. If the gradient is large enough, the wave will reflect back to earth at a long distance [Fig. 1]. The lower the radio frequency, the more easily the wave will be bent—that is, the smaller the required gra-

General Electric Co.

[2] Any aircraft approaching the east coast of North America from Greenland to Cuba can be seen on this display from the U.S. Air Force's AN/FPS-118 over-the-horizon radar. Different colors and symbols differentiate among target types. A red box with an H in it designates a potentially hostile aircraft, whereas an F in a white box defines a target that has been identified as friendly and probably has been matched with a flight plan.

dient. Launch elevation angles are typically in the range of about 1 degree (for maximum range) up to 25 or 30 degrees. For angles much greater than those, the propagating waves will penetrate the ionosphere. Hence, there is always a skipped zone of coverage within which an OTH radar cannot be used.

Even though there is no incident solar radiation at night, the ionization never decays completely—that is, there is always an ionosphere. So if one has complete freedom in frequency selection, it is always possible to illuminate the earth beyond the horizon.

The altitude region occupied by the ionosphere, while not constant, does not exhibit the extremes in variability shown by electron density. Because the height of maximum electron density varies only modestly, the potential area of earth surface covered by one refraction (hop) is reasonably constant even with density changes.

However, the frequency required to optimally illuminate a given area varies with changes in electron density and cannot be predicted precisely. Operating an OTH radar requires a real-time evaluation of the ionospheric path for frequency selection. That evaluation is carried out by a vertical sounder, an oblique sounder, and the radar itself.

Meanwhile, a separate receiver monitors channel occupancy in the HF band to see which channels are available. One of the unoccupied channels that falls in the optimal band can then be chosen for operation. To adapt to the environment over all times, a range of approximately 5:1 in operating frequency is required.

Applying digital technology

The initial MAgnetic Drum REcording (Madre) radar used by the Naval Research Laboratory in the 1960s to show off many of the HF radar possibilities was, in some ways, a simple system. Its single receive channel was processed through a 4-kilohertz filter bandwidth, resolving the system's processed range of approximately 500 nmi into about 20 range gates. Since the analog processing circuitry lacked enough dynamic range to handle both the desired target returns and the large sea echo, the receiver output was passed through a clutter rejection comb filter (one with notches at multiples of the radar's pulse repetition rate) to limit its dynamic range before it was processed.

Conceptually, the processing was done by a bank of filters, each with a bandwidth of less than a hertz. Actually, that function was carried out by a novel method of analog sampling and time compression using a magnetic drum, from which the radar got its name. The signal samples were recorded on the drum spatially packed and then read off some 83 000 times faster through a scanning narrowband filter. The time compression permitted using one scanning filter in place of a bank of narrow bandpass filters.

The original Madre signal processor occupied some eleven 6-foot (about 2-meter) relay racks. It required knowledgeable attention in setting levels throughout; and it could not detect the slower targets because they were rejected by the clutter filters.

The processor was replaced in the late 1960s by a hybrid analog-digital design that had sufficient dynamic range to process both targets and clutter. However, the hardware was even larger and heavier than the original Madre, and the system's digital magnetic-core memory was larger than the analog drum recorder. (Today, an inexpensive PC and a DSP chip can be programmed to outperform both of those early processors.)

To obtain the required signal purity, the Madre radar used crystal oscillators for signal synthesis, but adapting those oscillators to a constantly changing, user-filled spectrum was cumbersome and not altogether successful. Today, computer-controlled frequency synthesizers have signal-to-noise ratios comparable to those of the old crystal oscillators; yet they can switch frequencies almost instantaneously, and spectrum analyzers can be programmed to identify unoccupied channels. The two technologies can be combined to make frequency selection automatic.

Digital technology has also had an important effect in the related area of environment assessment and system flexibility in waveform and frequency selection with automatic calibration. The former enables real-time evaluation of the ever-changing transmission path and band occupancy, while the latter permits nearly instantaneous adaptation to the changing environment.

Computers also make a major contribution by automating target detection and tracking, which permits wide-area surveillance with a reasonable number of operators.

Advances in power amplifiers and antennas have also benefited HF OTH radar. Modern radars survey a broad area by sequentially stepping in azimuth and range. The range steps are accomplished by changes in frequency, while steps in azimuth depend mainly on phase changes for beam steering, but may require frequency changes as well. Clearly the transmitter of an OTH radar

must be able to change its frequency almost instantly.

Wideband, linear, vacuum-tube transmitters with reasonable efficiency first became available in the 1970s. Before, either low-efficiency distributed amplifiers or narrowband amplifiers were used. Now solid-state amplifiers with very wide passbands and high power levels are available.

The Madre antenna built in 1961 covered only a 2:1 frequency range, and its element lengths had to be mechanically adjusted for large frequency changes. Since the high-power final transmitter amplifier employed tuned narrowband circuits, antenna matching networks had to be adjusted for each change in steering angle or step in frequency. Today there are broadband frequency-independent antennas and computerized means for analyzing the behavior of phased arrays. For their oblique sounders, operational OTH radars in the United States use log periodic antennas capable of covering the entire HF frequency band.

All of these technological advances have made HF OTH radars easier to design and enhanced their performance. However, the single most important factor has been the orders-of-magnitude reduction in size, weight, and especially cost made possible by advances in digital signal and data processing.

Several systems

In U.S. Air Force and U.S. Navy OTH radars today, a set scans over about 60 degrees in azimuth in eight illumination sector steps: the transmitter covers the field with eight beams. The Relocatable OTH Radar (Rothr) receiver has 16 beams per transmitter sector step. The range coverage lies between 500 and 2000 nmi.

A system for covering 180 degrees of azimuth would take three radar sets. The area surveyed by scanning a 500-nmi-deep barrier over 180 degrees is more than 2 million square nautical miles, and that area can be divided into some 150 000 range-azimuth-Doppler resolution cells.

OTH radars in the United States typically operate in the FM-CW mode to maximize their average power. Since the transmitter is always on, the receiver must be located away from it for overload protection. Separation distances are dependent on the terrain, usually on the order of 80 to 160 km.

The U.S. Navy is in the process of testing the AN/TPS-71 Rothr, which can be transported to, installed, and put in operation at a previously prepared site in a matter of weeks.

An important task of the Rothr is to provide to Naval forces the tracks of approaching aircraft while the targets are still at a long distance. It can be used for: surveillance and tracking over a selected wide area; spotlighting regions of special interest; and assessing raid size. The Rothr system was designed and constructed by Raytheon Co., Lexington, Mass., and was installed and successfully tested at a site near Norfolk, Va.

The radar can be thought of as three distinct equipment subsets: those at the transmitter site, those at the receive site, and those at the Operations Control Center (OCC), which can be located at the receive site.

The U.S. Air Force recently completed acceptance testing of its first AN/FPS-118 OTH radar, which was designed, constructed, and installed in Maine by General Electric Co., Schenectady, N.Y. A second system on the West Coast is undergoing evaluation right now, and the others are in the planning stage. The AN/FPS-118 features a readily comprehensible display that makes good use of color to distinguish different target types [Fig. 2].

The Australian Defense Science Technology Organisation has been experimenting for more than a decade with its Jindalee radar. The name Jindalee comes from the Aboriginal word for "barebones"—an appropriate term for the austere first phase of the program. But now a first radar has been in a quasi-operational status, and Australia plans a network of HF OTH radars to furnish a large part of its long-range surveillance. The United States provided considerable assistance in the early stages of Jindalee; not surprisingly, therefore, the Australian radar has some features that are quite similar to those of U.S. radar equipment, most notably in the antenna and in the linear FM waveform.

For several years now, the Jindalee radar has also provided the Australian weather services with data on sea surface winds based on examination of the spectrum of the sea echo. Wind direction data derived from the U.S. Navy's Rothr has been shown to compare favorably with Fleet Numerical predictions.

In the late 1970s, many high-level radar-like signals were noted and traced to approximate sites within the Soviet Union. The signals used a bi-phase shift, pseudo-random type of pulse modulation. Analysis of the frequencies used suggests that the primary mission of the radar is the detection of U.S. ballistic missile launches.

The waveform used by the high-level signals had substantial frequency sidelobes, which spread over many conventional HF channel assignments and consequently interfered with many other services. In contrast, U.S. systems must plan to operate with waveforms and frequencies so as not to interfere with existing HF-band users. Experience with U.S. systems indicates that interference-free operation can generally be achieved.

Many technologies

Radar technology is often labeled as "mature," and indeed the basic idea of echo location is old. However, recent progress in the field has resulted more from the application of many technological developments than from a better understanding of radar fundamentals such as radio wave propagation or information theory. It is expected that radar capabilities will continue to improve as ever newer technologies become available, and as understanding of the environment increases.

For example, continued development in integrated circuits and in complex software will lead to improved processing capability, especially in trackers, where orders of magnitude improvement in system sensitivity is possible. Transmitters and transmitter antennas may also experience a radical increase in capability when digitally switched power supplies are used to put the desired current directly into each antenna element.

Continuing progress in gaining a better understanding of the ionosphere and transmission through and scattering from its irregularities are expected to advance actual performance.

To probe further

Only one book is devoted exclusively to over-the-horizon radar, *Fundamentals of Over-the-Horizon Radar*, in Russian, edited by A.A. Kosolov, Radio i svyaz, 1984. A translation by W.F. Barton was published by Artech House, Norwood, Mass., 1987.

Coverage of the field is also provided in Chapter 24 of the *Radar Handbook*, edited by M.I. Skolnik, 2nd edition, McGraw-Hill, New York, 1990. Chapter 24, "HF Over-the-Horizon Radar," by the current author, J.M. Headrick, contains abundant practical design data.

For a complete history of the Jindalee system, see "The Development of Over-The-Horizon Radar in Australia" by D.H. Sinnott, included in the Defense Science Technology Organisation's Bicentennial History Series, Australian Government Publishing Service, Salisbury, 1988.

The detection of ships at sea is covered by a guest editorial and several invited papers in *IEEE Journal of Oceanic Engineering*, Vol. OE-11, April 1986.

"Over-the-Horizon Radar in the HF Band," *Proceedings of the IEEE*, Vol. 62, pp. 664-73, June 1974, by J.M. Headrick and M.I. Skolnik, provides a solid theoretical backgrounder on the technology.

About the author

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Toward more compatible human-computer interfaces

Task analysis and rapid prototyping help computer engineers refine their products

As a larger and more varied mix of people begins to use personal computers, and as the competition for their business picks up, the need to improve the usability of human-computer interfaces becomes more urgent. Human factors—the study of what human characteristics imply for the design of equipment and systems intended to be used by people—play a key role in ensuring an effective interface.

Some features of the interaction are relatively well understood, especially those that human-computer interfaces share with hardware systems in general. But others, especially those that are more specific to computers, are not. Take menus and command languages, for instance [see "Defining terms," this page]. Menus may be preferred to command languages in some situations but not all, and for either input mode, design issues often have to be resolved on the basis of expert judgment. In menu design, depth must be traded off against breadth, and decisions made on how to name menu items. Similarly, in devising a command language, the names of commands and the syntax must be decided. Tradeoffs are involved in choosing scrolling versus paging, and it is often not clear how best to name programs, functions, and files.

These issues and others like them are being investigated with a view to developing general principles of interface design. As yet, though, guidelines are not sufficiently well developed to obviate all need for experimentation and adaptation. Current good practice is based on guided evolution, an iterative approach to the design process, abetted by the know-how that is accruing in the technical literature and among workers in the human factors field.

Designing flexibly

Guided evolution, or iterative design, guarantees design flexibility by intentionally leaving some system options open during the early stages. Then at a later point those interface features and functions can be selected in terms of how the user reacts. Two types of activities can facilitate this process: task analysis and rapid prototyping.

In task analysis, the designer develops a detailed understanding of the tasks the prospective user must perform and of how the system under development will help in their performance. Typically, in-house tools are used for task analysis. As an ongoing process, task analysis not only lays out in detail the task as initially understood but also tracks the way it changes as the user acquires new capabilities with growing familiarity with the system. This analysis can also help determine training requirements and staff levels for systems under development.

Rapid prototyping software tools quickly simulate some or all features of an actual interface. Because they serve a wide range of computing environments, they vary widely in their capabilities. Three packages representative of those used in industry and government for large system development on engineering workstations are: the Sherrill-Lubinski Graphical Modeling System (GMS) from Graphical Modeling System Corp., Madera, Calif.; Virtual Avionics Prototyping System (VAPS) from Virtual Prototypes Inc., Montreal, Que.; and Lockheed User Interface System and Softcopy Map System (LUIS/SMS) from Lockheed Missiles & Space Systems Co., Austin division, Austin, Texas. Any evaluation of such prototyping tools must take into account that they differ in many ways. The three mentioned above were evaluated by Donna Cuomo and Jane Mosier of the Mitre Corp., Bedford, Mass., in the table on p. 43, in terms of 11 features.

Other rapid prototyping tools include Demo II, Prototyper, and SuperCard. The first is for IBM PCs and compatibles, while the other two are for Macintosh computers.

Demo II can be used to demonstrate the operation of a program in a microcomputer, minicomputer, or mainframe using IBM's Common User Access standard for System Application Architecture. The program allows designers to test interfaces and functions with users without writing any code. Designed by Daniel Bricklin, the software is marketed by Sage Software, Beaverton, Ore.

Prototyper 2.0 is an integrated user-interface builder, simulator, and code generator. A designer interacts with the Macintosh mouse to create an interface. Once the interface is complete, the program generates custom-formatted source code. The program is sold by Now Software Inc., Portland, Ore. The other Macintosh tool is particularly well adapted to interfaces that give users the feel of directly manipulating images onscreen. Produced by

Raymond S. Nickerson and Richard W. Pew
Bolt Beranek and Newman Inc.

Defining terms

Bit-mapped graphics: a method of representing data in a computer for display in which each dot on the screen is mapped to a unit of data in memory.
Command languages: software in which commands are typed in, rather than selected from, a set displayed on the screen.
Dialog box: a rectangle that appears onscreen prompting the user to enter data or mutually exclusive selections.
Icon: a small graphic image on a computer screen that represents a function or program.
Menu: a list of command options currently available to the computer user and displayed onscreen.
Menu trees: successions of menu displays that become more detailed.
Multimedia: software that permits a mix of text, speech, and static and dynamic visual images.
Pull-down menu: a menu that appears onscreen when accessed by a cursor placed on a box or bar at the top of the display.
Window: a rectangular onscreen image within which the user accesses particular features of a system.

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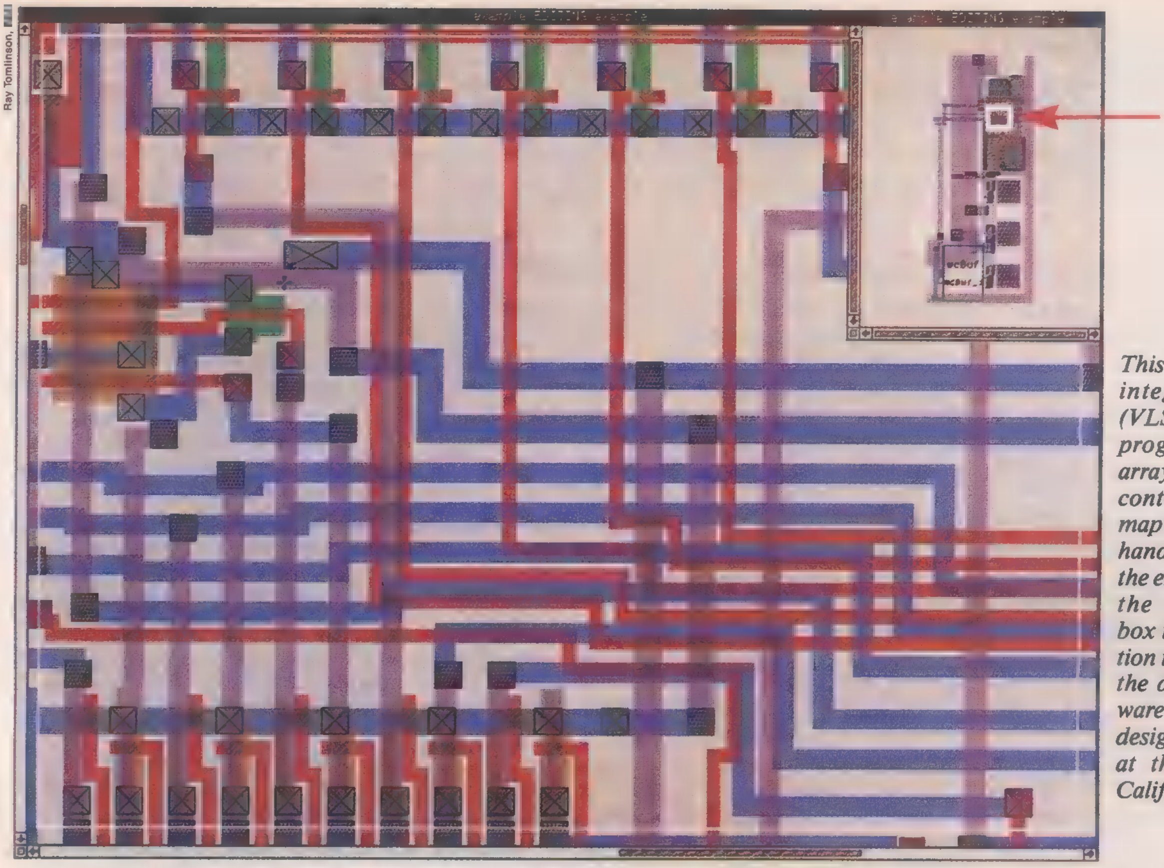
Ray Tomlinson,



This very large-scale integrated circuit (VLSI) design is for a programmable logic array for a network controller. The inset map in the upper right-hand corner displays the entire circuit, while the white-bordered box indicates the portion that is enlarged on the display. The software is Magic, a VLSI design tool developed at the University of California at Berkeley.

Silicon Beach Software Inc., San Diego, Calif., it can also convert a prototype design into a runnable application program.

At the prototype stage, it sometimes makes sense to have some functions of the ultimate system performed by people, without the knowledge of the user. This inverse simulation, in which a person mimics the planned performance of a machine, was employed in the early 1980s by John Gould, a researcher at the IBM Corp.'s Thomas J. Watson Research Center, Yorktown Heights, N.Y.

Gould wanted to determine how many words a speech recognition system needed to identify and how long a pause between words users could tolerate. So he asked users to sit before a monitor and treat it as a listening typewriter. However, a well-trained typist was sitting in another room listening and ready to enter what was said. Thus, when a user said a sentence, it would usually appear onscreen. But if the words spoken were not in a previously selected vocabulary, or were not adequately separated, they would not show up. Gould concluded that for a listening typewriter, isolated-word speech with large vocabularies, such as 1000 or 5000 words, could be nearly as good as connected speech systems for some applications.

Evaluating product design

Just as the process of designing interfaces must be dynamic, the evaluation of a product design as it is evolving should be ongoing, and the results constantly fed back into the design. Given the ability to build prototypes quickly, the challenge is to evaluate them cost-effectively enough and fast enough for the results to influence later design decisions. Otherwise, without information and feedback from potential users, the designer may make mistakes about what they will find important. The point is illustrated by the experience of Nicholas Simonelli and James Galambos of Prodigy Services Co., White Plains, N.Y. They helped design an on-line system that provides retail personal services through interactive software that runs on a personal computer.

On their system, a customer can order compact discs by selecting the artist or group either by scrolling the list and pointing or by typing in the artist's name; in either case, the selection of discs in stock then appears. If a customer who chose the typing method misspelled a name, the system was at first programmed to move down the alphabetically ordered list to the space just below the misspelled entry, leaving the correct entry often one line above the top of the display and the user confused because he does not see his request.

To resolve the problem, the analysts first considered matching the first n characters of the typed entry with the list entries and picking the most nearly identical. They found that best performance was achieved by searching only the first three characters of the entry. On a representative sample of entries, matching on five, four, and three characters produced 50, 25, and 8 percent errors, respectively. However, they chose a variation of the original method—placing the entry below the misspelled one in the middle of the displayed set—because it proved to require less processing time.

Several methods are used for evaluating prototypes. These range from qualitative assessments by hands-on users or observers to the use of benchmark tests (which in human factors parlance refers to measurements of the speed and accuracy with which a person performs standardized computer-aided tasks with a specific interface). Analytic modeling of the sequential and interactive constraints of tasks with two or more components can also provide a useful evaluation tool.

Evaluation criteria include: what the interface, and the system more generally, permit the user to do; how satisfied the user is; and how long it takes a person to learn to use the system to some specified efficiency level. Another criterion is how fast benchmark tasks can be performed. Also important are the robustness of the system under stress, error rates, and error costs.

For companies such as IBM Corp., Digital Equipment Corp., and Hewlett-Packard Co., interface software is a major component of their business. Being multinational companies, they are therefore working toward establishing global measures of interface performance with which to gauge the merits of different designs.

Some companies such as IBM, DEC, Xerox Corp., and NCR Corp. have also established usability laboratories, in which potential users of a system can interact with a prototype at various stages of its development. Typically these people are given the same training and documentation as are intended for the final users. Performance measures, often including videotaped records of work sessions, are obtained and the results used to guide further design.

Rules of thumb

System developers recognize a variety of principles as applicable to interface design in general, independently of the anticipated end use. To enlarge on the list in the table on this page, these include:

- Making it difficult to do something disastrous inadvertently, like deleting files unintentionally. Many systems require the user to confirm explicitly a request to delete a file and call the user's attention to the nature of the request made. Some also include a "nullify" or "undo" command, which permits retraction.
- Giving the interface user the feeling of directly manipulating the entities of interest, rather than of instructing the computer system to accomplish desired tasks. The stuff of typical direct-manipulation interfaces includes the mouse, track ball, joy stick, and touch screen; the high-resolution bit-mapped display; and icons that represent files, documents and other objects, or actions.
- Modularizing applications in terms of users' tasks. For example, users wishing to print a document want the what-you-see-is-what-you-get kind of copy and not a separate procedure for formatting the display.
- Using simple metaphors to communicate task organization. The Xerox Star introduced the concept of the computer screen as a desktop on which the user manipulates documents, files, and folders; the Apple Lisa added the handy trash basket, the icon for deleting files or other stored information. Similar metaphors are those of actor-on-a-stage and rooms-in-a-house.
- Allowing interactive access only when needed. In the 1970s menu trees often had to be traversed through an extended succession of screens. Today it is much easier to "bury" that complexity. The Macintosh, for example, uses a menu bar—a sequence of top-level menu selections always visible across the top of the screen—and pull-down menus that appear when one points and clicks on an item on the menu bar. When the selections under the menu bar do not sufficiently delimit the choices or the user must define specific attributes of the selection, it uses dialog boxes.
- Helping the user "navigate" within the information available. Typically when users interact with a computer-based system, they see displayed only a small portion of the available information of interest. This can create the problem of keeping their place in, or "navigating," the information space.

At Bellcore, Morristown, N.J., Thomas Landauer and his colleagues, George Furnas and Joel Remde, have developed a technique for giving the user a "fish-eye view" of electronic text, which lets him or her focus on an area of interest without forgetting where that area fits within the document's overall organization. A window shows a partial table of contents with an arrow indicating which section the main display represents.

An analogous problem is maintaining one's orientation when viewing magnified regions of a very large-scale integrated (VLSI) circuit design. For a VLSI circuit, the designer views different parts of the IC at various magnifications, and moves from a display of a circuit segment shown at one scale to another at a different scale. Some systems help the user stay oriented on a display of an IC section by overlaying a small inset map of the entire circuit [see figure on p. 41].

Many of these design principles have been applied in the multitasking application software called "Rooms," which Stuart Card and Austin Henderson developed at the Xerox Palo Alto Research Center in California. Each of the rooms represents a different working context and has a set of interactive display windows and tools associated with a task or project. To move from one room to another, the user sets the mouse cursor on the icon of labeled "doors" accessible from each room, and then presses the mouse key. Tools referred to as "baggage" are applicable to more than one room, but can be displayed in a different location or form in each.

According to Card, people typically define three kinds of rooms: task rooms, for activities such as generating and manipulating electronic mail; project rooms, for writing or programming; and management rooms, for monitoring systems or managing files.

Balancing needs

One of the most enduring challenges has been to design interfaces that meet the needs of both novice and experienced users. Beginners need a great deal of structure, walk-through procedures, and on-line assistance, and prefer selecting alternatives on the screen to typing in commands. Experienced users need less structure and system-volunteered assistance and may often prefer to type commands.

Less obviously, expertise with respect to a given system can vary in the same person. Any single user can be an expert with respect to some features and a novice with regard to others, and that expertise can rise or fall over time depending on regular or sporadic use. So what is needed is an approach that will accommodate all levels and mixes of know-how and make it easy for users to increase their degree and breadth of expertise.

Menu-driven systems typically provide novices with structure and guidance on available options. Many action options on the menus, however, may also be exercised by typed commands (usually two or three key strokes), so experienced users can save time if they know the commands. A helpful feature in some systems is the display of these mnemonic keystroke combinations that code the commands on the menu along with the commands themselves.

Some basic human factors design principles

Principle	Example
Make it hard for the user inadvertently to cause a disaster	Allow recovery from unintentional file deletion
Let the user feel he or she is doing the desired tasks directly rather than instructing the computer system	Enable direct manipulation of objects (such as selecting and moving icons with a mouse)
Modularize applications in terms of users' tasks, not programming convenience	Show the text as it will be printed without requiring a separate procedure for formatting
Use simple metaphors to explain task organization	Equate the computer screen to a desktop, on which users manage documents, files, and folders
Limit interactive access to when it is needed	Present a menu bar with various selections to obviate traversing successive screens
Help the user "navigate" within the information available	Give the global view in a small window, showing the text or image of interest in the rest of the screen

Looking ahead

What will future systems be like? Computer technology now opens up possibilities for multimedia, dynamic, interactive ways of representing information that were not feasible before, and these possibilities will be extended in the future. More effective ways of getting information from the user to the computer are also on the way, such as speaking, grasping, and simply looking. For instance, eye fixation and eye movements may be monitored and used as input signals to make menu selections or to indicate desired actions in other ways.

Systems will present information in an abundance

of representational forms, mingling text and speech and other sound with still and moving images and enabling users to explore large information stores dynamically and interactively.

In the near future, visual display technology is likely to advance on several fronts involving liquid-crystal and electroluminescent displays. Within the next decade or so, high-resolution color monitors with three-dimensional graphics should become widely available. High-definition, flat-screen television receivers promise large wall-mounted displays and are also likely to be a reality soon.

At the other extreme are three-dimensional and volumetric displays that may be worn on the head or attached to spectacles. Experimentation with head-mounted displays includes work on "artificial realities"—simulated environments, in which one interacts with the simulated entities much as with their counterparts in the real world—moving about, looking at objects from different viewing positions, picking things up, moving them around, and so forth.

One such "goggle-and-glove" interface is being applied to robotics by the National Aeronautics and Space Administration, according to Ann Lasko, design manager for its maker, VPL Research Inc., Redwood City, Calif. It is also being tried out for surgical simulation by the Veterans Administration, for instrument design by Boeing Co., and for visualization of abstract data by insurance companies, she said.

As systems become ever more versatile and are used by ever more people, issues of interface design and information representation will make an ever more important contribution to interactive computer-based systems' effectiveness.

Evaluation of three rapid-prototyping tools for large systems

Rapid prototyping tool	Graphical Modeling System	Virtual Avionics Prototyping System	Lockheed User Interface System/ Softcopy Map System
Prototyping: facilitation of iteration of design and test cycles	●	● ● ● ●	● ● ●
User interaction features (such as pull-down menus, icons, and windows)	● ● ●	● ● ●	● ● ● ●
Support for map displays produced from digital data	● ●	● ●	● ● ● ●
Provision for experimental data collection (such as keystroke sequences)	●	●	● ● ● ●
System response speed	● ● ● ●	● ●	● ●
Possibilities for display changes to accommodate independently supplied variable data	● ● ●	● ●	● ● ● ●
Ease with which unanticipated new capabilities may be added	● ● ● ●	● ●	● ● ● ●
Technical support	● ● ● ●	● ● ●	● ●
Support for more than one display device at a time	● ● ● ●	●	● ●
Portability among host computers	● ● ● ●	●	●
Support for more than one input device (mouse, trackball, or special-function keys)	● ●	● ● ● ●	● ● ●

● ● ● ● = best in category ● ● ● = good ● ● = some capability ● = poor

Source: Mitre Corp.

To probe further

Useful references are the four-volume *Engineering data compendium: Human perception and performance*, edited by K.R. Boff and J.E. Lincoln, and published in 1988 by Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, and *Handbook of Human-Computer Interaction*, edited by M. Helander and published in 1988 by Elsevier Science Publishers Co., Amsterdam, the Netherlands. Especially helpful is Section II: "User interface design," pp. 203–540.

Three books that describe human factors in interface design are: *Applying Cognitive Psychology to User-Interface Design*, edited by Margaret Gardiner and Bruce Christie, John Wiley & Sons, New York, 1987; *Using Computers: Human Factors in Information Systems* by Raymond S. Nickerson, MIT Press, Cambridge, Mass., 1986; and *User Centered System Design: New perspectives on human-computer interaction*, edited by Donald A. Norman and Stephen Draper, Lawrence Erlbaum Associates, Hillsdale, N.J., 1986.

Human-computer interaction is a journal of theoretical, empirical, and methodological issues of user psychology and system design, published by Lawrence Erlbaum Associates.

The Special Interest Group on Computer-Human Interface (SIGCHI) of the Association for Computing Machinery, New York City, sponsors an annual conference. CHI '90 was held in Seattle, Wash., during April 1–5. The proceedings are available for nonmembers from Addison-Wesley Publishing Co., Reading, Mass.; 800-447-2226. CHI '91 will be held in New Orleans, La. Contact: Keith Butler, Boeing Advanced Technology Center, M/S 7L-84, Box 24346, Seattle, Wash. 98124; or John Thomas, Director, AI Lab (OG4), Nynex Science & Technology, 500 Westchester Ave., White Plains, N.Y. 10604.

The Human Factors Society also sponsors an annual conference, the Human Factors Society Annual Meeting. The one this year will be held Oct. 8–12 at the Stouffer Orlando Resort in Orlando, Fla. Proceedings of the meeting will be available at the conference and by ordering from the society. Contact: Human Factors Society, Box 1369, Santa Monica, Calif. 90406; 213-394-1811.

Interface design is also discussed in "Interfaces for advanced computing" by James D. Foley, *Scientific American*, October 1987, pp. 126–135.

The September 1989 *IEEE Spectrum* includes a design case history titled "Of mice and menus: designing the user-friendly interface," pp. 46–51, by Tekla S. Perry and John Voelcker. The December 1984 issue of *Spectrum* has a related article titled "Design case history: Apple's Macintosh," pp. 34–43, by Fred Guterl.

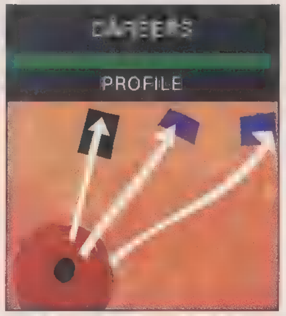
About the authors

Raymond S. Nickerson is a senior vice president of BBN Systems and Technologies Corp., a subsidiary of Bolt Beranek and Newman Inc. in Cambridge, Mass. Nickerson has conducted basic and applied psychological research in areas such as perception, memory, decision-making, reaction time, and human factors aspects of highway safety, in addition to person-computer interaction. A member of the National Research Council (NRC) Committee on Human Factors since 1988, he holds an M.A. in experimental psychology from the University of Maine, Orono; and a Ph.D. in experimental psychology from Tufts University, Medford, Mass.

Richard W. Pew (M) is a principal scientist and manager of the experimental psychology department at BBN Systems and Technologies Corp. He has been involved in several U.S. Air Force projects to develop design methodology for introducing human factors analysis in automated systems. He was president of the Human Factors Society in 1977 and founding chairman of the NRC Committee on Human Factors. He received a BEE from Cornell University in Ithaca, N.Y.; an A.M. in psychology from Harvard University, Cambridge, Mass.; and a Ph.D. in psychology from the University of Michigan in Ann Arbor.

The right kind of accidental career

Whether in the Pentagon, NASA, or corporate boardroom, Robert S. Cooper promotes technological breakthroughs with fervor



A towering figure with a baritone voice and a loud laugh, Robert S. Cooper in conversation switches easily from Soviet mobile missiles to Japanese gallium arsenide chips; from tradeoffs in nonlinear optics to laser remote sensing; and from excessive Government secrecy to lackluster U.S. competitiveness. In his numerous jobs, he has helped improve worldwide navigation for pilots and mariners, upgrade U.S. remote sensing, herald modular spacecraft, and jump-start hypersonic research.

Some associates characterize him as "excessively ambitious" or "hard to approach." But others almost idolize him. Lynn Conway, a University of Michigan professor who worked for Cooper at the Defense Advanced Research Projects Agency (Darpa), calls him "a rare combination of technology visionary and organizer-manager" who has had "the right kind of accidental career." Ahmed Neer, who earned a Ph.D. at the Massachusetts Institute of Technology (MIT) in Cambridge with Cooper and 12 years later worked for him at the National Aeronautics and Space Administration's (NASA's) Goddard Space Flight Center, said, "The main thing about Bob is he really believes in whatever he's doing and that's really contagious."

Cooper himself simply says he's "an unabashed technologist."

Baseball was the first thing Cooper believed in. Slinging fastballs and sliders won him a full scholarship to the University of Iowa in Iowa City, but after several years, as he delved deeper into his electrical engineering studies, the obsession with sports gave way to an interest in medicine and electronics. He got an academic scholarship and gave up baseball.

The Korean War was at its peak. So after graduation and before pursuing a doctorate, he joined the Air Force Reserve Officers Training Corps for two years. There the young engineer was entrusted with far more responsibility than would have been his good fortune in industry: he oversaw more than a dozen contractors to develop a B-47 short-range navigation system for testing accuracy of the beeline bombing system.

John A. Adam Senior Associate Editor

After that, the question was: what kind of doctorate? Since his interest by this time was radio astronomy, he applied to several colleges and was accepted on a Westinghouse Fellowship at Ohio State University in Columbus, where he expected to work on an L-band phased-array radar. But a professor persuaded him to pursue medical electronics instead. (During his senior year in college, he had developed instrumentation for pharmacological research.)

Completing his master's in biotechnology, Cooper worked at the school hospital devising an X-ray cinematography machine. At this point, he was undecided whether to pursue medicine at Iowa State University or engineering at MIT. He tossed a coin, and Cambridge won, even though he knew that would take him away from bioengineering. In Cambridge, while he taught undergraduate circuit courses and learned the fundamentalist MIT way of thinking, Cooper analyzed plasma and wave propagation for his doctorate and minored in mathematics.

Since he liked teaching, he accepted MIT's offer to continue doing it after he received his doctorate, fully expecting to spend the rest of his career as a professor. He also consulted for MIT-affiliated Lincoln Laboratories in Lexington, which was doing ballistic missile defense work for the recently formed ARPA (the "D" was a later addition). His focus was radar discrimination of warheads.

"The interesting thing is, you could design a [fully effective] system in those days," Cooper said. In the 1960s, he recalled, the attacker had only a few hundred warheads, and multiple-warhead missiles had not yet been devised. (Although he never believed a large-scale Strategic Defense Initiative system could be practical, as a Government employee he did his best to start the program in 1983.)

In 1968, the consulting work became a full-time job when escalating campus protests against the Vietnam War drove Cooper from campus. "I spent less and less time teaching," he commented. At Lincoln Labs, he extended his work to lasers and to the spectral signatures of missiles and warheads, and soon rose to division director. By now in his mid-thirties, he met many laser researchers at the national laboratories and in industry, and trav-

Vital statistics

Name: Robert S. Cooper
Born: Feb. 8, 1932, in Kansas City, Mo.
Education: BSEE, the University of Iowa in Iowa City; MSEE, Ohio State University, Columbus; Ph.D., Massachusetts Institute of Technology, Cambridge
Family: wife Benita Ann; two sons by previous marriage, Jonathan and James
First job: analog computer programmer at Sidewinder missile project at China Lake, Calif.
Favorite food: Japanese stir-fried anything
Books most recently read: *Hunt for Red October*, *Made in America*
Favorite periodicals: *IEEE Proceedings*, *IEEE Spectrum*, *Architectural Digest*
Leisure activities: sailing, skiing, tennis, and renovating houses
Managing credo: "Hard work and smart associates are the keys to success"
Persons most admired: NASA's George Low, inventor-photographer Harold E. "Doc" Edgerton, and Loran pioneer Ernie Guillemin
Pet peeves: "People who quit"; people who "verbize" nouns, adjectives, and adverbs
Proudest feats: "Overcoming the bureaucracy and helping in a small way to start" these programs: Navstar Global Positioning System; Multimission Modular Spacecraft; Search and Rescue Satellite; Strategic Computing; Sp-100 space nuclear reactor; and the national aerospace plane

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Jim Pickerell

A tour through the Smithsonian's National Air and Space Museum becomes almost a personal reminiscence for Robert S. Cooper, who during three stints in Government influenced worldwide navigation, spacecraft, and strategic computing (for which he attained the IEEE Fellow grade).

eled to Washington, D.C., to consult with the Pentagon's John Foster. Foster soon asked Cooper to be an assistant, coordinating high-energy laser research among the services, overseeing small agencies, and handling intelligence projects. He also worked with NASA as Department of Defense (DOD) coordinator for the nascent space shuttle project.

The assignment to Washington was to be only temporary—three years—and it bewildered Cooper at first. "So many decisions were based on things other than the facts," he said, and there were so many ways to stymie plans. "It blew my belief system right out of the water."

But he adjusted quickly. He was most proud of the constraints he put on the laser program so Congress would not waste money on the "sexy" technology until it proved itself. He also helped start the Joint Service Navstar Global Positioning System project, combining the separate, less capable Navy and Air Force programs and funding basic research in atomic clocks, which are critical for accuracy. It was 16 years before the system started working, but "it's revolutionary and important for military and civilian navigation," he said. "I'm proud of that."

Cooper's next stop was not the expected return to Lincoln Labs. Just before his Pentagon stint ended, he got a call from NASA. George Low, its deputy administrator, had worked with Cooper on the shuttle planning and now asked the 43-year-old engineer to run the Goddard Space Flight Center in Greenbelt, Md.

Goddard was unique among NASA centers in being virtually self-contained. Staffed with some 3700 scientists, engineers, and support personnel and enjoying an annual R&D budget of some $800 million, the center launched its own rockets, built its own spacecraft and instruments, operated 14 tracking sites around the world, and devised new theories on space and earth science.

Since he'd contemplated a doctorate in radio astronomy, space had always intrigued Cooper, so he agreed to serve four years. (He is adamant about keeping Government service stints to three or four years—as he puts it, enough to make a difference but not long enough to build a fiefdom that might stifle new ideas. Also, salaries are low, he adds realistically.) He severed his ties with MIT.

NASA budgets were declining, however, and Cooper's job was to reshape Goddard. He centralized control and declared it would work on a single new flight project at a time, not three.

After four years, NASA chief Robert Frosch asked Cooper to stay. But he needed to make money to help his two boys through college. His expertise in space landed him a job at Satellite Business Systems (SBS) as vice president of engineering. In three years, he helped launch SBS's digital communications system.

Then in 1981, he was offered "the best engineering job in the world—anything else has got to be an anticlimax." Richard DeLauer, DOD's research undersecretary of defense, asked him to become director of Darpa, a small agency with a sizeable purse responsible for exploring technological frontiers. In contrast to "slow-grinding bureaucracies"—like the DOD, NASA, and the National Institutes of Health, all agencies where, Cooper said, 10 people can say no to every proposal—Darpa has only two: the program manager and the director. "If two guys agree, you can do a lot of R&D—even create a whole new technical discipline," he noted.

He feels the United States has a serious problem in investing in and managing its technology. In Government, "in order to fund anything, we have to create an initiative," he said. "We have to hype the whole thing."

"Large sums" of SDI money are for "demonstrating progress so you can get more money next year," he added. During his first two years at Darpa, Congress refused the increase in basic research he advised, so to get money, "we had to dream up initiatives"—usually with a mission-oriented outcome in a mere five years. Examples include strategic computing, gallium arsenide, hypersonic research, and a number of classified programs.

"Why do we have to resort to all this hype and subterfuge?" Cooper asked, then added, "We don't do a good enough job explaining to the populace the benefits of basic research."

Despite his accomplishments, during Government stints Cooper had to use up savings and compromise on the time he spent with his family and friends. Today, he lives in a modest neighborhood in Washington, D.C., and has his own startup company, Atlantic Aerospace Electronics Corp., in Greenbelt, Md.

Such enthusiastic commitment to technology has earned Cooper much loyalty. Of the staff of some 150, many Atlantic Aerospace employees are former associates from NASA or Darpa; some even date to his MIT days.

Cooper, who still works 60- to 80-hour weeks, has no regrets about pursuing what interests him. "It never makes you much money," he said, "but you sure have fun." ◆

MARCH 1930

Van de Graaff's generator

Megavolt at $90

The new 35-M/ V Vivatron accelerator being tested in Strasbourg, France, marks the latest step in meeting a technological challenge first taken up by a young Rhodes Scholar back in 1925.

Robert J. Van de Graaff was 24 when he went to Oxford that year. Soon afterward, he encountered a question in his physics text that "remained in my mind as a sort of challenge," he recalled later: why was it impossible to build an electrostatic machine with a large power output?

A memorandum he produced in 1933 reveals that his first major insight was that he could accelerate ions and electrons to "enormous" energies by generating a high voltage in a vacuum. At the same time, he recognized that direct current would be preferable to "the more usual sources which have alternating, rippling or impulsive characteristics."

Actual experimental work had to wait until September 1929, when the new Ph.D. arrived at Princeton University in New Jersey to work under physicist Karl T. Compton on a National Research Council (NRC) fellowship. Only a month later, Van de Graaff was able to show Compton the first model of his electrostatic generator. Its operating principle was explained formally the following March in a report that, as a fellow, Van de Graaff had to write for the NRC.

Referring to the drawing shown, he wrote: "A motor driven pulley P drives by means of the belt B a second pulley Q, which runs freely. The belt is of insulating material, but has at intervals carriers of conducting material. As these carriers pass under the inductor I, maintained at a considerable negative potential by an auxiliary Whimshurst machine, there is induced on each carrier a bound positive charge, while the free negative charge escapes to earth through the grounded metal pulley P. Thus the carriers move away toward the anode A carrying a positive charge, which they retain until they make contact with the metal pulley Q, situated in the interior of the anode and connected with it. At this contact the carrier gives up its entire charge to the surrounding anode and then returns uncharged to the first pulley P. In this way positive charge is continually brought up by the moving belt to the anode, so that its potential rises steadily, either until a constant potential is reached at which the leakage from the anode becomes equal to the input current, or until a spark passes."

The electrostatic machine was easy to build. The first model, dubbed "the tin can generator," had a belt made of silk ribbon bought at the local five-and-dime (where, the story goes, Van de Graaff alarmed the salesgirl by testing the ribbon's flammability). Operated in the open air, it reached a potential of 80 000 volts.

A few months later, Van de Graaff generated over 1 000 000 V between two 60-centimeter-diameter spheres on Pyrex columns 180 cm high. This version was published Oct. 28, 1931, in a three-page "Disclosure of invention," signed by Van de Graaff and two witnesses. The apparatus cost $90.

Van de Graaff's generator made headlines when it was demonstrated in New York City on Nov. 10, 1931, before a dinner meeting of the newly formed American Institute of Physics. "Atom Nucleus Seen Yielding To Science," declared *The New York Times* in a front-page story, which reported that the Massachusetts Institute of Technology (MIT) in Cambridge was embarking on machines capable of generating up to 15 million volts. *Time* magazine hailed the "$90 Lightning." Compton called it "the most important development that has ever taken place in the field of extremely high voltages."

Van de Graaff followed Compton to MIT in November and devoted the rest of his life to building more powerful and sophisticated electrostatic accelerators for industrial, scientific, and medical applications. He applied for a patent on Dec. 16, 1931, and assigned it to MIT in 1933 under an agreement that gave him 20 percent of the net income up to a maximum of $400 000.

On March 18, 1935, MIT vice president Vannevar Bush wrote Van de Graaff to inform him that patent 1 991 236 had been issued on Feb. 12. "It is a good looking patent, and I hope that our dreams in connection with it may some day come true," Bush added. In the light of the frontiers of nuclear research and cancer treatment the invention opened up in the ensuing years, it is likely those dreams were realized.

Michael F. Wolff Contributing Editor

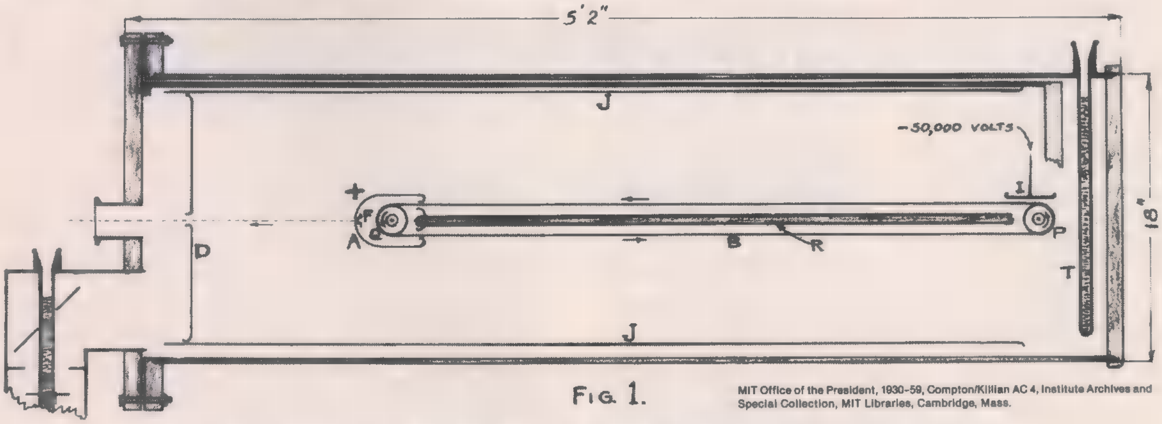

FIG. 1.

MIT Office of the President, 1930-59, Compton/Killian AC 4, Institute Archives and Special Collection, MIT Libraries, Cambridge, Mass.

The small electrostatic generator shown in this March 1930 diagrammatic cross section marked the start of Robert J. Van de Graaff's search for an artificial source of copious high-energy radiation.

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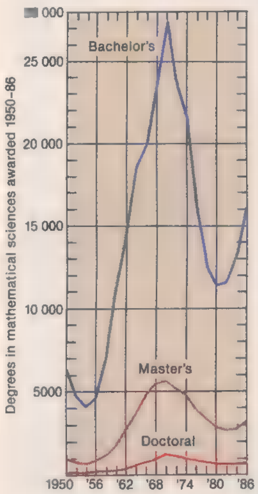
Math students, faculty dwindling

By the year 2000, the U.S. demand for scientists, engineers, and technicians needing a mathematics background may exceed the 1986 demand by [redacted] percent, nearly double the growth of total employment demand, according to [redacted] recent National Research Council (NRC) report. Moreover, by 1995, the college-age population may drop 22 percent from its 1981 level. "Unless positive steps are taken, the nation's needs for mathematically skilled . . . workers for business, industry, and government will not be met," the report states.



Source: National Research Council

As one example of this trend, total bachelor's degrees conferred in mathematical sciences numbered 16 306 in 1986, a level first surpassed in 1964. Although degrees awarded have fluctuated since then, they peaked at 27 442 in 1970 and then tended downward [see figure].

The report—"A Challenge of Numbers: People in the Mathematical Sciences"—is the second of three issued by the NRC's Committee on Mathematical Sciences in the Year 2000. It costs $9.95 (prepaid) from the National Academy Press, 2101 Constitution Ave., N.W., Washington, D.C. 20418; 800-624-6242.

Wanted: minority engineers

Although blacks make up 12 percent of the population, they comprise only 2 percent of employed scientists and engineers, according to a report by the Task Force on Women, Minorities, and the Handicapped in Science and Technology. The Washington, D.C., organization was established by the U.S. Congress to develop a plan for widening participation in these careers.

In 1988, only 47 blacks earned doctorates in science, 15 in engineering. Hispanics, at 9 percent of the population, comprise only 2 percent of employed scientists and engineers; they hold 3 percent of the bachelor's and 2 percent of the doctorates in science and engineering.

American Indians, who account for 0.6 percent of the population, make up 0.5 percent of employed scientists and engineers, while holding 0.3 percent of bachelor's degrees and 0.11 percent of doctorates.

White women make up only 10 percent of all employed scientists and engineers, despite forming 43 percent of the U.S. population. They received 22 percent of bachelor's degrees and 13 percent of doctorates in science and engineering.

The report—"Changing America: The New Face of Science and Engineering"—advises doubling the number of women getting bachelor's in these fields, tripling black enrollees, and increasing the Hispanic students by a factor of seven.

It suggests that universities set quantitative goals for recruiting, that school boards set higher graduation requirements, and that professional societies become educational advocacy groups and supply financial and other assistance.

For [redacted] copy, write to the Task Force on Women, Minorities, and the Handicapped in Science and Technology, 330 C St., S.W., Room 2014, Washington, D.C. 20201.

Coordinator: Gary Stix
Consultant: Mary Golladay, National Science Foundation

Nuclear waste

(Continued from p. 24)

ing of low-level wastes has become nearly routine in some countries. The French Government, with Europe's largest nuclear operations, has met relatively little resistance to its program to establish low-level sites.

In September, it authorized the licensing for a low- and intermediate-level waste disposal site at Soulaines in the department of L'Aube, 200 kilometers southeast of Paris. Site preparation had begun [redacted] early as 1987 and waste will be accepted starting next year. The L'Aube installation will replace the existing low-level disposal facility in La Manche. The older site, next to the reprocessing plant at Cap La Hague, is approaching its capacity of 500 000 cubic meters.

Shallow burial for low-level wastes has not met with universal acceptance, however. Sweden's Forsmark facility for low- and intermediate-level wastes will store up to 200 000 m^3 of byproducts from the country's 12 nuclear reactors, including ion-exchange resins and filter material from different nuclear-plant water-treatment systems. Forsmark, which is located northeast of Stockholm, is a series of chambers built 60 meters under the Baltic Sea.

Sweden plans to phase out nuclear power by 2010, although two of the reactors may be shut down earlier. The layout of the tunnels and caverns at Forsmark [redacted] designed so that the repository could be extended to accept wastes from the decommissioning of nuclear power plants.

Like France, the United Kingdom uses shallow disposal methods. But the 40 000 m^3 it generates annually of low-level wastes cannot be placed indefinitely at the Drigg facility four miles south of Sellafield, which will be filled between 2020 and 2030. Drigg uses [redacted] concrete-lined trench to store waste in steel boxes, each holding twelve 200-liter drums.

In the United States, political conflict has complicated the search for [redacted] comprehensive low-level waste-management policy. Legislation by the U.S. Congress required each state to come up with a plan for managing its own commercial wastes by [redacted] early [redacted] 1985. This would have taken the onus off the only three U.S. low-level disposal sites, in Washington, South Carolina, and Nevada. When the deadline was not met, Congress decided to defer it until 1993.

Many states have formed regional compacts that will pool resources and decide on one site; states that are not in [redacted] compact by the new deadline will have to find [redacted] solution to disposing of their own wastes. According to a 1989 report by the Office of Technology Assessment in Washington, D.C., not every state will be able to comply by 1993.

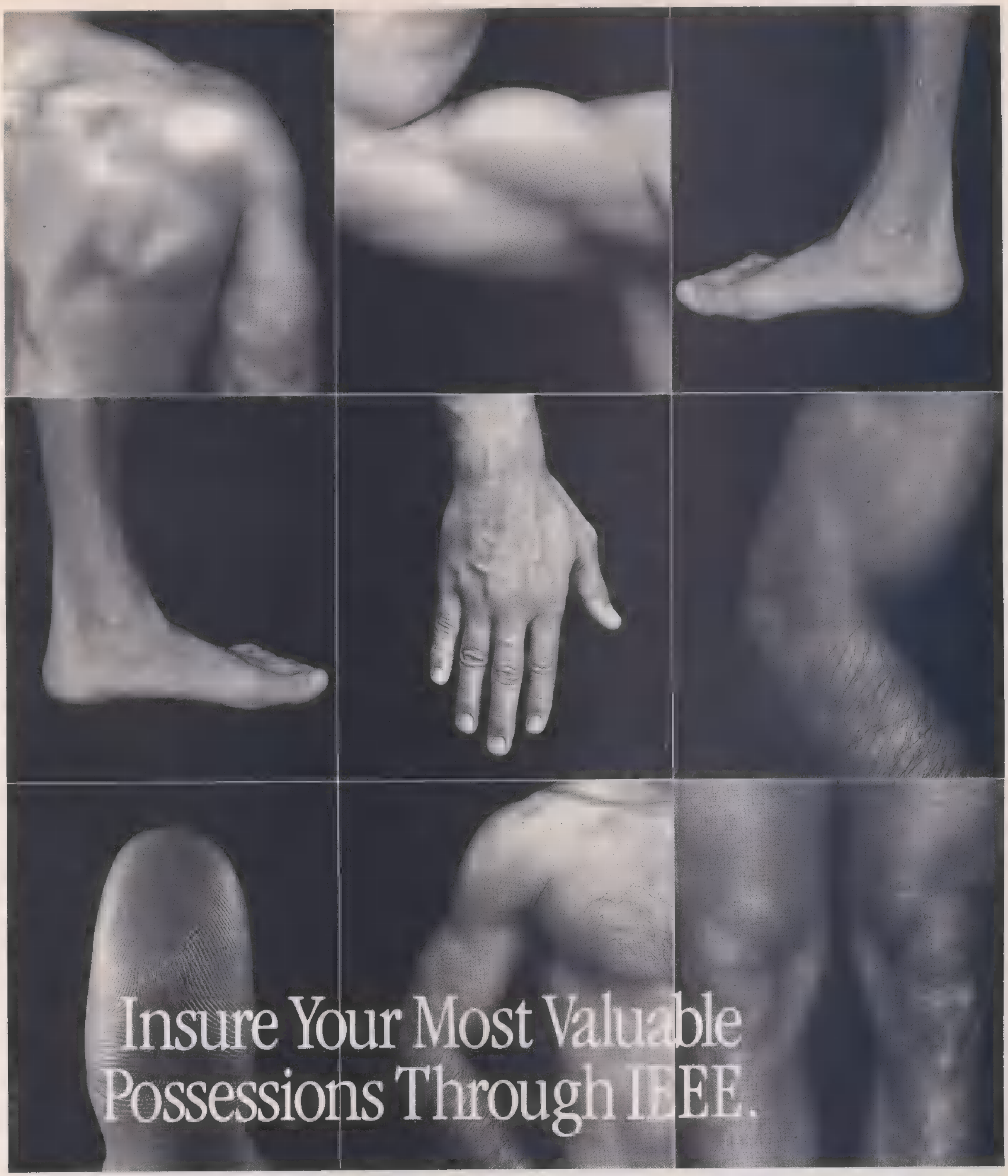
To probe further

The *IAEA Bulletin*, the quarterly journal of the International Atomic Energy Agency, published [redacted] survey last year (Vol. 31, No. 4) of radioactive-waste disposal efforts worldwide. Articles include an overview, [redacted] technology report, [redacted] look at safety standards, and [redacted] assessment of waste disposal in developing countries.

The problems involved in low-level waste disposal in the United States are outlined in "Partnerships Under Pressure: Managing Commercial Low-Level Radioactive Waste," published by the U.S. Congress' Office of Technology Assessment in November 1989.

"High Level Radioactive Waste Management" is [redacted] two-volume set of proceedings from a conference held last April in Las Vegas, Nev. The proceedings are available from the American Nuclear Society, LaGrange Park, Ill. (708-352-6611). The same organization publishes *Nuclear News*, which often covers waste management. In particular, see the May 1990, February 1990, and March 1987 issues. ◆

Research and reporting for these articles were contributed by Roger Milne and Simon Rippon in London and Ian Anderson in Melbourne, Australia.


Insure Your Most Valuable
Possessions Through IEEE.

Your word is my command

At least since 1953, when Isaac Asimov in his science fiction classic *Second Foundation* told how 14-year-old Arcadia Darrell dictated a term paper into her Transcriber "and copy was turned out in a charming and entirely feminine handwriting," some have dreamed of devising a machine that can translate talk into written text. Now DragonDictate, described as the first commercial general-purpose voice-driven typewriter, comes a big step closer to realizing that dream.

Announced in March by Dragon Systems Inc. of Newton, Mass., it is the first commercial speech recognition system with a large vocabulary of 30 000 words that learns from someone talking fairly naturally rather than from limited sets of words spoken in a preordained order, according to chief executive officer James K. Baker. The system consists of a speech recognition board, a microphone, and software, and requires an IBM PC/AT-compatible computer configured with 8M bytes of RAM and an Intel 80386 microprocessor running MS-DOS.

The user must pronounce discrete words, separating them by a pause of about a quarter second. He or she also calls for punctuation, such as "comma" or "open quote," just as to a human stenographer. For words that sound alike but have different meanings, such as "to," "too," and "two," the system displays a menu of possible words from which the user selects the right choice with keyboard or voice. Once accustomed to the system, users can create text at a rate of 30 to 40 or more words per minute.

Perhaps the most important innovation is the system's use of what Baker calls multiple sources of knowledge. Instead of relying on, for example, either phonemes (basic sound units) or allophones (phoneme variations that arise in actual speech) or syntax (position of words in sentences) or semantics (meanings of words) or artificial intelligence or rule-based techniques, the DragonDictate incorporates aspects of all these techniques. By combining them with statistical modeling, it recognizes discrete words accurately 90 percent of the time.

Unlike other commercial systems, it does not have to be trained by a user, say, reading aloud a long list of words or speaking words in a rigid order. Two kinds of software models enable immediate recognition of about 25 000 common words. Acoustic models of speaker-independent words tell the software how each should sound. Statistical language models rate the likelihood of a word from its context. A backup dictionary lists 80 000 words in spelling only, minus acoustic models; it also has room for an additional 5000 words the user can define, which can include proper names, acronyms, technical terms, or even commands. Through it all, the system learns the pronunciation of its user, so accents or speech impediments, if consistent, do not impair its performance.

The DragonDictate is aimed chiefly at people working in "hands busy/eyes busy" applications, such as radiologists who read X-rays and dictate diagnoses in the dark or disabled people who cannot use a keyboard. It should also appeal to non-typists who pay out enough for stenographic services to make DragonDictate's $9000 tag look good.

Dragon Systems is now working on a system for recognizing Spanish and other languages. Ultimately it hopes to develop technology for recognizing continuous speech as well as discrete words.

Write on!

Speaking of writing, another Massachusetts company—Neurogen Inc. of Brookline—has developed *IN*SCRIPT, a character recognition system that identifies unconstrained handwritten numbers and financial symbols. The symbols can be written by any user and the system identifies them at the rate of three characters per second with an accuracy of up to 99.5 percent. By using a neural network method, *IN*SCRIPT learns to read numbers much as the human brain does. The product can be used to automatically enter data on envelopes or other standard forms.

Most optical character recognition systems (OCRs) use either template matching or rule-based feature-detection techniques. In template matching, the scanned character is compared with a template having a basic rendition of the character. In a rule-based system, a programmer defines the features of the strokes that make up the character and a measure is made of how closely the scanned character matches the definition.

*IN*SCRIPT, by contrast, develops its own rules and learns through experience. The system assigns to known information weighted values based on an algorithm that learns associations between signal patterns and pattern classes.

The sequence of steps involved in recognizing a handwritten number are: scanning the image, filtering it from a gray-scale image to a binary image, locating a handwritten number field on the form, isolating each number in the field, and classifying it through use of a neural classifier.

The system—a plug-in printed-circuit board, which includes a digital signal processor and interface software—runs on an IBM PC/AT, Compaq 286, or any computer 100 percent compatible with them. The computer needs 256K bits of RAM, a 20-megabyte hard disk, and MS-DOS 3.1 or higher. The system works with just about any scanner to convert handwritten numbers into a form compatible with such applications as word processing, desktop publishing, and database programs.

Coordinators: Trudy E. Bell and Ronald K. Jurgen
Consultants: Ralph H. Baer and Homer Jensen

Organizations seeking engineers and scientists describe their various openings in the following advertising section

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(Continued from p. 14L)

Fifth Jerusalem Conference on Information Technology (COMP); Oct. 22-25; Jerusalem Congress Center, Jerusalem, Israel; Joshua Maor, IBM Israel, 2 Weizman St., Tel Aviv 61336, Israel; (97+23) 618 618.

International Conference on Signal Processing '90 Beijing (Beijing Section et al.); Oct. 22-26; Beijing; Zong Sha, Nongzhan Guan, Nan Lu 12, Room 2307, Beijing 100026, China; (50+011) 44 2307.

Global Telecommunications Congress and Exhibition-INTER COMM 90 (Vancouver Section); Oct. 23-26; Vancouver Trade and Convention Centre, Vancouver, Canada; INTER COMM 90, 777 Pacific Boulevard, South, Vancouver, B.C. V6B 4Y8, Canada; 604-669-1090.

Visualization '90 (COMP); Oct. 23-26; Le Meridian, San Francisco; Stephen Levine, Wang Laboratories (MS 012-250), 1 Industrial Ave., Lowell, Mass. 01851; 508-967-0798.

MAECON '90 (IEEE, ERA); Oct. 24; Henry VIII Hotel, St. Louis, Mo.; Jim Leonard, Box 1075, Florissant, Mo. 63031; 314-925-6828.

22nd Symposium on Stochastic Systems Theory and its Applications-ISCIE (IEEE Control Systems Society et al.); Oct. 24-26; Hiroshima Information Museum, Hiroshima, Japan; Y. Sunahara, Kyoto Institute of Technology, Matsugasaki, Sakyo-ku, Kyoto 606, Japan; (81+75) 721 7086.

Conference on Physical Concepts of Materials for Novel Optoelectronic Device Applications (ED, MTT et al.); Oct. 27-Nov. 2; Congress Center, Aachen, West Germany; Anne Noteboom, SPIE, Box 10, Billingham, Wash. 98227; 206-676-3290, ext. 116.

Conference on Electrical Insulation and Dielectric Phenomena (IEEE); Oct. 28-Nov. 1; Pocono Manor Inn, Pocono Manor, Pa.; Reuben Hackam, Department of Electrical Engineering, University of Windsor, Ont. N9B 3P4, Canada; 519-253-4232.

International Power Meeting-India (PE); Oct. 28-Nov. 1; New Delhi, India; T. W. Hissey Jr., Leeds & Northrup, Sumneytown Pike, North Wales, Pa. 19454; 215-699-2000.

Conference on Magnetism and Magnetic Materials (MAG); Oct. 29-Nov. 1; Town and Country Hotel, San Diego, Calif.; Courtesy Associates Inc., 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-5088.

Compsac '90 (COMP); Oct. 31-Nov. 2; Holiday Inn Mark Plaza, Chicago; Stephen Yau, CIS Department, 301 CSE, University of Florida, Gainesville, Fla. 32611; 904-335-8006.

NOVEMBER

Engineering in Medicine and Biology Society 12th Annual Conference (EMB); Nov. 1-4; Wyndham Franklin Plaza Hotel, Philadelphia; Nihat M. Bilgutay, Electrical and Computer Engineering Department, Drexel University, Philadelphia, Pa. 19104; 215-895-2257.

LEOS Annual Meeting in conjunction with Optcon '90 (IEEE/LEO); Nov. 4-9; Hynes Convention Center, Boston; Glenda McBride, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855; 201-562-3896.

Singapore International Conference on Communication Systems-ICCS '90 (IEEE Singapore Section et al.); Nov. 5-9; Pan Pacific Singapore Hotel, Singapore; Meeting Planners Pte. Ltd., 100 Beach Rd., Suite 33-01, Shaw Towers, Singapore 0718; (65+13) 297 2822.

Computer Society Conference on Tools for AI-TAI '90 (COMP); Nov. 6-9; Hyatt Hotel, Washington, D.C.; Nikolaos G. Bourbakis, George Mason University, Department of ECE, Fairfax, Va. 22030; 703-425-3930.

Workshop on VLSI Signal Processing (ASSP); Nov. 7-9; Sheraton Grand Hotel, San Diego, Calif.; Howard S. Moscovitz, Bell Laboratories, 1247 S. Cedar Crest Blvd., Allentown, Pa. 18103; 215-770-3644.

International Conference on Computer-Aided Design-ICCAD '90 (COMP et al.); Nov. 12-15; ICCAD '90, Santa Clara Convention Center, Santa Clara, Calif.; IEEE Computer Society, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036; 202-371-1013.

Supercomputing '90 (COMP et al.); Nov. 12-16; New York Hilton Hotel, New York City; Su-

(Continued on p. 50J)

HONEYWELL: OPENING THE DOOR TO AVIONICS TECHNOLOGY OF THE 90s.

Honeywell in Phoenix offers a variety of career opportunities in our Commercial Flight Systems Group. Our continuing growth has created the following positions:

Systems Design Engineer — In this area, you will be involved in guidance and control systems analysis and hardware/software design trade-offs. Specification designs, including guidance, navigation and control algorithm development, as well as systems integration and installation, flight test and customer liaison activity, are a part of these positions.

System Software Development — This area involves development of flight software for advanced guidance and control systems for aircraft using modular and structured programming techniques. You will be involved with algorithms and development of real-time programs in both assembly (8086 family Z8002, 68000) and high order languages such as Pascal, "C," Ada and PLM/86, with subsequent hardware integration.

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- CAE Engineering (Apollo Mentor Systems)
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- VAX Systems Administration
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CALENDAR

(Continued from p. 50F)
percomputing '90, IEEE Computer Society, Conference Services, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036; 202-371-1013.

Wescon '90 (Region 6 et al.); Nov. 13-15; Anaheim Convention Center, Anaheim, Calif.; Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, Calif. 90045; 213-772-2965.

Second Annual SEPRI Symposium-Industrial Electric Power Applications (PE et al.); Nov. 15-16; Doubletree Hotel, New Orleans, La.; Jack Davey, Department of Electrical Engineering, Tulane University, New Orleans, La. 70114; 504-865-5785.

International Conference on Spoken Language Processing-ICSLP (ASSP et al.); Nov. 18-22; International Conference Center Kobe, Kobe, Japan; Hiroya Fujisaki, Department of Electronic Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan; (81+3) 812 4442, ext. 6656.

Cognitiva '90 (COMP); Nov. 20-23; Madrid, Spain; IEEE Computer Society, Conference Services Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036; 202-371-1013.

16th Annual Conference of IEEE Industrial Electronics-IECON '90 (IE); Nov. 27-30; Pacific Grove, Calif.; Robert Begun, 23609 Skyview Terrace, Los Gatos, Calif. 95030; 408-353-1560.

DECEMBER

Global Communications Conference-Globecom '90 (COM); Dec. 2-5; Sheraton Harbor Island Hotel, San Diego, Calif.; Andrew Cohen, Qualcomm Inc., 10555 Sorrento Valley Rd., San Diego, Calif. 92121; 619-587-1121, ext. 326.

First International Symposium on Uncertainty and Analysis: Fuzzy Reasoning, Probabilistic Methods, and Risk Management (COMP et al.); Dec. 3-5; University of Maryland, College Park, Md.; Bilal M. Ayyub, Department of Civil Engineers, University of Maryland, College Park, Md. 20742; 301-454-2438.

Fourth International Workshop on CASE-CASE '90 (COMP); Dec. 3-8; Irvine, Calif.; Elliott J. Chikofsky, Radius Systems Inc., 75 Lexington St., Burlington, Mass. 01803; 617-494-8200, ext. 552.

Third International Conference on Computer Vision-ICCV '90 (COMP); Dec. 4-7; Osaka, Japan; ICCV '90, IEEE Computer Society, Conference Services, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036; 202-371-0101.

29th Conference on Decision and Control (CS); Dec. 5-7; Hilton Hawaiian Village, Honolulu, Hawaii; Malcom D. Schuster, RF-23-377, Johns Hopkins University, Applied Physics Laboratory, Laurel, Md. 20707.

Ultrasonics Symposium (UFFC); Dec. 5-7; Sheraton Waikiki Hotel, Honolulu, Hawaii; Moises Levy, Physics Department, University of Wisconsin, Milwaukee, Wis. 53201; 414-963-4168.

(Continued on p. 50L)

(Continued from p. 50J)

Workshop on Heterogeneous Database Systems (COMP); Dec. 11-13; Northwestern University, Evanston, Ill.; IEEE Computer Society, Conference Services, 1730 Massachusetts Avenue, N.W., Washington, D.C. 20036; 202-371-1013.

JANUARY 1991

Fourth CSI/IEEE International Symposium on VLSI Design (COMP et al.); Jan. 5-8; New Delhi, India; Y.K. Malaiya, Computer Science Department, Colorado State University, Fort Collins, Colo. 80523; 303-491-7031; or D. Roy Chowdhury, Gateway Design Automation, SDF- A-1, Noida Export Processing Zone, P.O. NEPZ, Noida-201305, UP, India; (91+57) 366 2342.

FEBRUARY

Power Engineering Society Winter Meeting (PE et al.); Feb. 3-7; Penta Hotel, New York City; J. G. Derse, 704 Timber Brook Dr., Bedminster, N.J. 07921; 201-725-4388.

Aerospace Applications Conference (South Bay); Feb. 3-8; Telluride, Colo.; Steve Swift, 15216 Burbank Blvd., Van Nuys, Calif. 91411; 818-989-1133.

Winter Convention on Aerospace and Electronic Systems–Wincon '91 (AES et al.); Feb. 26-28; Los Angeles; George Oltman, 23411 Dolorosa, Woodland Hills, Calif. 91367; 818-341-4010.

MARCH

Applied Power Electronics Conference and Exposition–APECT '91 (PEL); March 11-15; Hyatt Regency Dallas, Dallas; Ann Beightol, Courtesy Associates, 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-347-5900.

International Conference Control '91 (UKRI Sec.); March 25-28; Edinburgh Conference Centre, Heriot-Watt University, Edinburgh, Scotland; Louise Bousfield, IEE Conference Services, Institution of Electrical Engineers, Savoy Place, London WC2R OBL, England; (44+1) 240 1871; fax, (44+1) 240 7735.

APRIL

Southeastcon '91 (Region 3 et al.); April 7-10; Fort McGruder Inn, Williamsburg, Va.; Griffith G. McRee, 525 Virginia Deare Dr., Virginia Beach, Va. 23451; 804-683-4897 (O) or 804-428-0083 (H).

Infocom '91 (C, COM); April 7-11; Sheraton Bar Harbour, Bar Harbour, Fla.; Ken Joseph, Bell Canada, 160 Elgin St., Ottawa, Ont. K1G 3J4, Canada; 613-234-7214; fax, 613-234-1442.

1st International Workshop on Interoperability in Multidatabase Systems (C0); April 8-9; Kyoto University, Kyoto, Japan; IEEE Computer Society Conference Services, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Reliability Physics Symposium (ED, R); April 8-11; Caesars Palace, Las Vegas, Nev.; Alfred L. Tamburrino, RADC/RBRP, Griffiss AFB, N.Y. 13441-5700; 315-330-2813.

International Symposium on Subscriber Loops and Services–ISSLS '91 (COM et al.); April 22-25; Raicongrescentrum Europaplein, Amsterdam; Paul 't Hoen, PTT Netherlands, Box 39, 2260 AA Leidsehenam, The Netherlands; (31+70) 43 22 33; fax, (31+70) 43 21 40.

MAY

IEEE/IAS Industrial and Commercial Power Systems Conference–I&CPS '91 (IA); May 6-9; Hilton Inn, Memphis, Tenn.; Allan H. Long, Memphis Light, Gas & Water Division, Box 430, Memphis, Tenn. 38101-0430; 901-528-4859.

Compeuro '91–IEEE Fifth International Conference on Advanced Computer Technologies, Systems, and Applications (COMP et al.); May 7-10; Bologna, Italy; V. A. Monaco, Dip. Elettronica, Informatica e Systemistica, University of Bologna, Viale Risorgimento 2, 1-40136, Bologna, Italy.

Power Industry Computer Applications Conference–PICA '91 (PE); May 7-10; Hyatt Regency/ Sheraton, Baltimore, Md.; William Keagle Jr., Baltimore Gas & Electric Co., Electric Test Facility-RBC, Box 1475, Baltimore, Md. 21203; 301-281-3788.

What Xerox is to copiers . . .

Occasionally a company so dominates a particular market or technology that its name becomes closely identified with the product. For example, people still regularly talk about *xeroxing* a document, even when the machine spewing out the copies is made by Canon Inc. or Mita Copiers instead of Xerox Corp. Likewise, in the United States, at least, one looks for *Scotch tape*, rather than cellophane tape, to wrap a package; for a *Kleenex*, rather than a facial tissue, to cover a sneeze; and for a *Band-aid*, instead of a plastic bandage, to protect a cut.

Usually, such association is rather flattering, even if it does irk those in charge of making sure that trademarked names are not misused. But Exxon Corp. is probably not pleased that *exxon* is being turned into a verb that alludes to the company's

exxon /'ek-sän/ *v:* to spill large quantities of oil, especially in water, creating environmental damage

recent oil spills in Alaska's Prince William Sound and near Staten Island, New York. An example of this usage appeared in the *Washington Post*: "I tried to change the oil in my car, and I *exxoned* the whole driveway." In fact, the *American Heritage Dictionary* is tracking the verb's usage for possible inclusion in a future edition.

This brings up an interesting question. Is any electronics company, other than Xerox, so closely identified with a technology, product, or phenomenon, whether in a positive or unflattering way, that its name is used as a verb?

A few product names lend themselves to this trend. IBM Corp. even encouraged it with the advertising campaign for its PS/2 series of personal computers: "How're you going to do it? PS/2 it!" Similarly, one could *VAX* a program, instead of running it, on a Digital Equipment Corp. VAX minicomputer.

Few other potential ones come to mind. For example, both Hewlett-Packard Co. and Apple Computer Inc. are famous for having been started in the founders' garages. If someone is starting a business from the ground up in this manner, he might tell acquaintances that he is trying to *HP* it.

But there is certainly ample room for confusion here, especially when the company or product name or acronym is actually a word—or sounds like one. For example, turning Digital Equipment's commonly used acronym DEC into a verb could be a little awkward and perhaps humorous: one would then speak of *DECing* a program. Usually, the user wants to deck the computer, not the program, although most often the problem lies with the software rather than the hardware. And how about referring to *Sunning* a program (for Sun Microsystems Inc.) or *NeXTing* it (for NeXT Inc.)?

It's enough to make you glad that company and product names and verbs seldom mix.

I say data, you say Daten

A recent column discussed the similarity of many technical terms in English and various European languages [May, p. 20]. But some of these terms are vastly different, so English-speaking engineers may have a tougher time communicating in Europe than Technically Speaking originally thought.

For example, the verb *compute* has fairly logical counterparts in French, Italian, and Spanish: *calculer*, *computare*, and *computar* or *calcular*, respectively. But in German, it is *berechnen*.

Similarly, *telecommunications* translates very easily into French, Italian, and Spanish: *télécommunications*, *telecomunicazione*, and *telecomunicación*, respectively. German is a different story: *Fernmeldetechnik*. An English-speaking engineer fumbling for the correct word in German would not be likely to come up with that one.

Data, however, is a little more complicated. In Italian, it is *dati*, which certainly sounds similar. In German, it can be *Werte* or *Daten*; likewise, it is *antecedentes* or *datos* in Spanish. But in French, it is *données*.

What does this mean for the English-speaking engineer thinking of working in Europe? Well, to some it might indicate that they should think twice before heading off to German-speaking countries. Wherever they decide to go, having a thorough knowledge of the country's language certainly seems a good idea—whether they will be interpreting *dati* or designing *telecomunicación* systems.

On time but still too late

Language is frequently manipulated by companies and governments to make unpleasant news sound more innocuous; thus, workers are *negatively impacted* rather than *laid off*, and so on. However, the executives who run some of the plane and train services in India must have been truly inspired to dream up *preponed*, which they use to describe flights and trains whose departure times have suddenly been moved forward. There is usually no attempt to contact passengers affected by the schedule changes, and refunds are not given. Such an invention is almost enough to make travelers grateful when they must wait at the airport because their flights are merely *postponed*; at least they know that when it eventually leaves, they will be on it.

Coordinator: Erin E. Murphy
Consultants: Anne Eisenberg, Polytechnic University; Pamela McCorduck, Columbia University

Maps in motion

Within two years, PC users of the "Global Change Encyclopedia" could be viewing colorful satellite data on vegetation, land masses, ocean currents, and coastlines as they shift around the world. That information is now being entered into an animated atlas, one of 10 projects sponsored by the Space Agency Forum on International Space Year (Safisy), a group established last year to coordinate space agency planning for 1992, designated International Space Year by the United Nations.

The encyclopedia will allow viewers to use compact-disc read-only memory to see land and sea changes in motion over extended periods of time.

Satellites gathering the information include a U.S. National Oceanographic and Atmospheric Administration Landsat satellite, the high-resolution French SPOT-1 satellite, and the Japanese ocean-observation MOS-1 satellite. Resolutions range from 10 to 80 meters.

The first edition will be out in 1992. Future editions scheduled include data on greenhouse effect detection, sea surface temperature measurement, land cover changes, and ocean productivity.

Safisy headquarters, now at the National Space Development Agency of Japan, in Tokyo, rotates annually among the 25 participating space agencies. *Contact: ISY Information Service, 600 Maryland Ave., S.W., Suite 600, Washington D.C. 20024; 202-863-1734.*

EDUCATION

Surface mounting on video

For design and manufacturing guidelines to creating surface-mounting packages that will be inexpensive to assemble and test, engineers and designers can turn to a new videotape training program. Its sponsor is the Society of Manufacturing Engineers (SME), Dearborn, Mich.

Titled "Surface Mount Technology: Design for Manufacturability," the program examines the interrelationships between surface-mounting technology designs, assembly processes, cleaning, testing, and quality control. Six videotapes lasting about four hours and a 300-page reference guide are included. The videotapes, available in 1/2-inch VHS or 3/4-inch U-Matic formats, cost $1995 to nonmembers ($1895 to SME members). A 14-minute preview tape costs $25 (SME members, $21). *Contact: SME, Publication Sales Department, One SME Drive, Box 930, Dearborn, Mich. 48121-0930; 313-271-1500, ext. 418 or 419.*

PERIPHERALS

Entering data by voice

Engineers whose eyes and hands are too tied up to use a keyboard—such as those who inspect wafers, vehicles, or aircraft—can resort to a user-trainable voice input/output system for data entry. It provides more than 99 percent accuracy, according to the manufacturer, Burr-Brown Corp., Tucson, Ariz.

The TM5200, which links to a host computer or an RS-232C ASCII terminal, recognizes up to 600 words of continuous speech that it stores in a solid-state cartridge. Each user must train the peripheral for several hours, preferably in the end-use environment, by confirming the words that the system repeats. To use the TM5200, he or she inserts the cartridge and speaks into the microphone of a wired or radio-frequency headset. Because the system is user-dependent, it accepts all languages.

Available now, the TM5200 costs $6500. *Contact: Paul F. Smith, Burr-Brown Corp. Box 11400, Tucson, Ariz. 85734; 602-746-1111; fax, 602-889-1510.*

Coordinator: Katherine T. Chen
Consultants: Jack M. Kinn, Electronic Industries Association; Paul A.T. Wolfgang, Boeing Helicopter

Dressing up your PC

PC users who are young at heart or who want friendlier PCs can buy a different kind of "softwear" to dress up their monitors: four cuddly creatures—a green dragon with a tail, a gray bulldog wearing a collar, a toothy pink rabbit holding a carrot, and a brown teddy bear.

"Computer critters" are plush doll-like parts—heads, arms, and legs—that attach to the top, sides, and front of a monitor. One side of the hook-and-loop fastener strips is sewn onto the doll parts and the other side is adhesive-backed for taping onto the monitor's surface. Removal and repositioning will not harm the monitor surface, but the parts can be repositioned only a few times.

Celsus Designs Inc.

The dragon and bulldog retail for $34.95 each, and the rabbit and teddy bear, $29.95 each. A cat and a football player are other characters being planned. *Contact: Celsus Designs Inc., Box 5401, Hacienda Heights, Calif. 91745; in the United States, 800-869-9229; elsewhere, 818-333-7273.*

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

Advertising rates

Positions open: $32.00 per line, not agency-commissionable

Positions wanted: $32.00 per line, [redacted] 50% discount for IEEE members who supply their membership numbers with advertising copy

All classified advertising copy must be received by the 25th of month, two months preceding date of issue. No telephone orders accepted. For further information contact Wendy I. Goldstein, 212-705-7578.

IEEE encourages employers to offer salaries that are competitive, but occasionally [redacted] salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

Academic
Positions Open

The University of Alabama in Huntsville The Department of Electrical and Computer Engineering invites applicants for tenure track positions at all faculty ranks. The Department had 630 undergraduate majors and 220 active graduate students. Position qualifications include U.S. citizenship or permanent resident status, Ph.D. in Engineering, ability to teach at all levels, supervise M.S. and Ph.D. candidates, and pursue funded research in [redacted] such as communications, optical engineering, computer engineering, or modern electronics. Huntsville, a high-technology city, offers congenial living, a unique cultural environment, and many opportunities for Summer employment. Positions will remain open until they are filled. Send resume with names and telephone numbers of three references to: Chair, ECE Department, UAH, Huntsville, AL 35899. Telephone: (205) 895-6316. UAH is an Affirmative Action/Equal Opportunity Employer.

University of California, Irvine Department of Radiological Sciences Faculty Position in Medical Imaging. The University of California, Irvine, Department of Radiological Sciences, has an opening for a faculty position [redacted] Assistant Professor or Assistant Professor In-Residence in Medical Imaging. The candidate must have [redacted] Ph.D. in physics or engineering with proven research experience, and, preferably, administrative expertise. Individuals with broad interdisciplinary research interests are encouraged to apply. Experience in MRI and/or nuclear imaging is desirable. Applicants should have previous experience inacademic institutions. Research experience, which includes [redacted] successful record in obtaining contract and grant support is desirable. The level of appointment and salary is dependent upon the candidates's experience and academic achievements. Candidates should send their curriculum vitae, statement of research interests, and the names of five references to: Richard M. Friedenberg, M.D., Professor and Chairman, Department of Radiological Sciences, University of California, Irvine Medical Center, 101 City Drive South, Route 140, Orange, CA 92668. The University of California is an Equal Opportunity and [redacted] Affirmative Action Employer.

University of Arkansas, Electrical Engineering Faculty Position. The Department of Electrical Engineering, University of Arkansas, has [redacted] faculty position available January 1991 in the area of power systems. Applicants must have an earned doctorate. Duties include undergraduate and graduate teaching and research. Send applications including [redacted] list of references to Head, Department of Electrical Engineering, University of Arkansas, Bell Engineering Center-3217, Fayetteville, Arkansas 72701. The University is an Equal Opportunity/Affirmative Action Employer.

The Department of Electrical Engineering, University of Florida, is seeking applications for the chairmanship. This position is tenure accruing and the concurrent faculty appointment is Full Professor of Electrical Engineering. The salary is dependent upon qualifications and experience. Individual applicants should have a distinguished research and teaching record with demonstrated interest in academic administration. Applications are invited to arrive no later than July 30. Early applications are encouraged as the position is open beginning Fall Semester 1990. Send application with resume and list of references to: Chair, Search Committee, 216 Larsen Hall, Department of Electrical Engineering, University of Florida, Gainesville, FL 32611. The University of Florida is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply. According to Florida law, applications and meetings regarding applications [redacted] open to the public on request.

University of Houston, Department of Electrical Engineering, Faculty Position in Applied Geophysics. The Department of Electrical Engineering invites applications for [redacted] faculty position in the applied geophysics [redacted] available in January 1991. Preference will be given to candidates with a Ph.D. degree, several years of industrial experience, and an established record in seismic and/or digital signal processing research. The candidate is expected to be [redacted] senior member of the Allied Geophysical Laboratory, [redacted] industry-supported consortium, and to serve as a liaison to the ongoing improved oil recovery and well logging research programs. A background in engineering would be desirable. Applications and resumes, together with the names and addresses of three references, should be sent to: Dr. L.C. Shen, Department of Electrical Engineering, University of Houston, Houston, TX 77204-4793. An Equal Opportunity Employer.

Chairman, Electrical Engineering University of Pittsburgh. Nominations and applications are invited for the position of Professor and Chairman, Department of Electrical Engineering at the University of Pittsburgh. Candidates should possess a vision of the future directions for Electrical Engineering and have the leadership and managerial skills to promote and implement that vision. The successful candidate must have a demonstrated record of excellence in both teaching and research. An earned doctorate is required. The Electrical Engineering Department has 24 tenure stream faculty members spanning the [redacted] of computer engineering, electronics, signal processing, communications, systems, control, and power. The Department offers BS, MS, and Ph.D. degrees, and has [redacted] enrollment of approximately 340 undergraduate students (sophomore through senior level), and 180 graduate students. The University of Pittsburgh, entering its third century, has established a strong tradition of education, research and service and is [redacted] member of the select American Association of Universities. The Electrical Engineering Department celebrates its centennial anniversary in 1990. This position will be filled by September 1, 1991. Nominations or applications, including resume and names and telephone numbers of references should be sent before October 1, 1990 to: Professor Larry J. Shuman, Associate Dean of Engineering, Chairman of Electrical Engineering Search Committee, University of Pittsburgh, Pittsburgh, PA 15261, Telephone: 412-624-9814. The University is an affirmative action and equal opportunity employer.

South Australian Institute of Technology Professor of Computer Systems Engineering. Applications are invited for appointment to the Foundation Chair in Computer Systems Engineering. This is expected initially to be a joint appointment in the School of Electronic Engineering and the School of Mathematics and Computer Studies at The Levels Campus. The position is tenurable. It is anticipated that the Institute will be redesignated [redacted] a university by 1991. The appointee will provide leadership in the further development of teaching programs and initiation of research activity in Computer Systems Engineering. A demonstrated ability to attract applied research funding and research students is highly desirable. The position requires [redacted] person who is a professional engineer with [redacted] strong interest also in computer science/software engineering. The School of Electronic Engineering has established a strong and unique research record in selected areas of electronic engineering including digital communications, microelectronics, and measurement and instrumentation. Research in Computer Studies has focused primarily in the areas of software productivity tools, human-computer interaction and manufacturing support. Interaction with industry provides excellent opportunities for all collaborative research and consultancy. Both Schools have well equipped laboratory facilities and a wide range of computing facilities. The current salary for a Professor is A$65,837 per annum. Opportunities for private consulting would enable the salary to be augmented. Further details about the position may be obtained from: Prof. R.S. Northcote, Head of Computer Studies, Tel: +61 [redacted] 343 3202 Facs: +61 [redacted] 349 4367 EMail: marsn@levels.sait.edu.au. Applications, including [redacted] detailed curriculum vitae and names and address of three referees should be forwarded to Mr. Grant Wiles, Recruitment Officer, S.A. Institute of Technology, GPO Box 2471, Adelaide, SA 5001 Australia by 31st August, 1990. The Institute reserves the right to consider late applications or fill the post by invitation. REF. MACS009. The Institute is [redacted] Equal Opportunity employer and smoke-free working environment.

Iowa State University, Ames, Iowa. The Department of Electrical and Computer Engineering seeks applicants for faculty positions at the associate or full professor level starting August 1990. Particular interests include computer networks, distributed computing, data communications. The department supports a networking research and teaching lab which contains over $250,000 of equipment. Supported networks include: Starlan, Ethernet, Token Ring, ISDN, with plans to add token bus and FDDI. Funded projects include: integrated voice/data/voice networks, transport protocols for internetworking, and high-speed control bus protocols. Applicants should be committed to teaching excellence, extension, and a demonstrated ability to obtain peer reviewed publications and external funding. Interested persons should send [redacted] curriculum vita and [redacted] list of 3 referencse to Dr. John Lamont, Chairman Faculty Search Committee, 201 Coover Hall, Iowa State University, Ames, IA 50011. Phone 515 294-2663. Internet: lamont@isuee1.ee.iastate.edu. Iowa State University is [redacted] Equal Opportunity/Affirmative Action Employer.

Dynamics and Control of Machines and/ or Structures Position in the Engineering College at Ohio University. Duties include undergraduate-graduate teaching and research with emphasis on large flexible structures. Assistant or Associate Professor, dependent upon the applicants's credentials and qualifications. Can-

didate must have an earned doctorate in Engineering and demonstrated potential for teaching and research. Review of applications begins July 15, 1990 and continues until position is filled. Send letter of application, resume and names of three reference and citizenship/immigration status to Dr. Glenn A. Hazen, 141 Stocker Center, Ohio University, Athens, Ohio 45701. Ohio University is an equal opportunity/affirmative action employer.

New Zealand, University of Canterbury, Post-Doctoral Fellowship (Electrical and Electronic Engineering) Applications are invited for a two-year University Grants Committee Post-Doctoral Fellowship in the Department of Electrical and Electronic Engineering to participate in research related to the display and perception of multidimensional data. Candidates should have a strong background in physics and/or electrical and computer engineering and a doctorate in an area relevant to the research topic. A good level of competence in computer programming is required together with a knowledge of one or more of the following areas: 1) digital electronic systems design; 2) high vacuum technology; 3) computer graphics/image processing. The successful applicant will work closely with a team of three academic researchers (one physicist, two electrical engineers) and a number of (post) graduate students in the development of a 3-dimensional display device (currently in prototype form), the transformation of k-dimensional data sets into m-dimensional display spaces (m<k) and various aspects of the perception of images, natural and synthesised. Applicants must be aged 35 years or less and have been awarded, or have qualified for the award of, the degree of Doctor of Philosophy, or a degree equivalent thereto, or who have submitted a thesis for examination. The age limit may be relaxed in special circumstances or in order to avoid hardship to an applicant for a Fellowship. The emolument for a Fellowship shall be at a rate not exceeding the lowest step of the Lecturer salary scale ($NZ36,000 per annum). Enquiries may be directed to Dr P.J. Bones, Department of Electrical and Electronic Engineering (Fax 64 3 642 705). Before submitting a formal written application, candidates are requested to obtain Conditions of Appointment from the undersigned. Applications, quoting Reference Code C90/01, close on 31 July 1990 and must be addressed to: A.W. Hayward, Registrar, University of Canterbury, Private Bag, Christchurch, New Zealand.

Research in integrated optics including the development of a technique to characterize the optical properties of organic semiconductor waveguide devices, & the design, fabrication, characterization of III-V compound optoelectronic devices. Investigate the electronic & optical properties of III-V compound & organic semiconductor heterojunctions. Req: Ph.D. in Electrical Engineering, three years research experience, specialized knowledge of integrated optics, semiconductor device technology and high vacuum systems. Sal: 634.62/week, 40 hrs/week, Job/interview site: Los Angeles, CA. Send this ad and a resume to Job #JM15075, P.O. Box 9560, Sacramento, CA 95823-0560, not later than July 30.

Engineering Research Associate—Stanford University seeks an engineering research associate to develop an advanced three-dimensional semiconductor device analysis program. Duties include developing advanced numerical analysis techniques and implementing parallel solution and other routines on advanced computer hardware which includes Intel 1860 based message-passing parallel computer. S/he will also be responsible for interaction with industrial sponsors and users of the code. The position requires a knowledge of the field of numerical analysis, device physics, integrated device electronics and a familiarity with the programming environment of Intel iPSC computer series. Ph.D. in Electrical Engineering required. Salary $48,000 per year. Send application and resume to Administrator, AEL 205, Stanford University, Stanford, CA 94305 no later than Aug. 1st, 1990.

Research Position in Applied Ocean Science, University of California, San Diego. The Marine Physical Laboratory, Scripps Institution of Oceanography, invites applications from scientists for appointments at the Postgraduate Research, Assistant Research, or Associate Research level. Applicants with an interest in conducting innovative experimental work at sea will be given strongest consideration. Fields of interest include, but are not limited to, sonar or ocean acoustics, geology, geophysics, physical oceanography, autonomous or tethered submersible vehicles, radar oceanography, and marine micrometeorology. Applicants should have a Ph.D. Postgraduate Research and Assistant-level candidates will be expected to show evidence of their potential through letters of recommendation ad a publication record appropriate for theri experience. Associate-level candidates must show evidence of a strong research record in their specialization. Salary will be commensurate with experience and qualifications and based on UC pay scale. Immigration status of non-US citizens should be stated in the resume. There is the possibility that more than one appointment can be made. Closing date for applications is July 31, 1990. Direct inquiries to Dr. W.S. Hodgkiss, Marine Physical Laboratory, Scripps Institution of Oceanography, San Diego, CA, 92152. (619) 534-1798. The University of California, San Diego is an equal opportunity/affirmative action employer.

Southwest Missouri State University Head, Industrial Technology Department. The Department of Industrial Technology at Southwest Missouri State University invites applications for a tenured, Department Head position. Responsibilities include teaching, service, research, and support faculty in these areas. Other duties include administering all aspects of the department, actively seek resources to support industrial outreach initiatives, provide active leadership and commitment to affirmative action programs, coordinate the development of ABET-TAC accreditation programs, and to coordinate with a director the accreditation of IT programs in Industrial Management and Industrial Technology. The department consists of 17 full-time faculty with over 400 majors. Additional per course faculty are employed to assist with special and evening programs. Applicants should have an appropriate advanced engineering degree and doctorate from an accredited institution. Administrative and/ or leadership experience in higher education with three years of industrial experience. Salary commensurate with experience. Closing date: August 1, 1990. Submit letter of application, resume, official transcripts, names and telephone numbers of three current references to: Chairperson of Department Head Search Committee, Department of Industrial Technology, Southwest Missouri State University, 901 South National Avenue, Springfield, MO 65804-0094. SMSU is an Equal Opportunity/Affirmative Action Employer.

Associate Director—Industrial Liaison, Center for Telecommunications Research. Responsibilities include representation of technical innovations to participating industrial companies and development of new corporate affiliates. A strong technical background in leading-edge telecommunications is required. Ph.D. in EE desired but not essential. Send resumes to attention of: Prof. A.S. Acampora, CTR, Columbia University, 500 W. 120th St., Suite 1206, New York, NY 10027. Columbia University is an affirmative action/ equal opportunity employer. We encourage applications from qualified women and minorities.

New Zealand University of Canterbury Senior Lecturer or Lecturer Electrical and Electronic Engineering. Applications are invited for a position, as above, in the Department of Electrical and Electronic Engineering. Expertise is expected in one or more of the following areas: digital signal processing; data, radio-frequency, microwave, optical or satellite communications; microelectronics, VLSI, computer networks. Applicants must have appropriate academic qualifications and a record of research or industrial experience. The salary for Senior Lecturers is on a scale from $NZ50,000 to $NZ58,600 per annum and a range from $NZ60,800 to $NZ64,500, and for Lecturers is on a scale from $NZ36,000 to $NZ43,700 (bar), and a scale from $NZ45,000 to $NZ47,200 per annum. Applications close on 31 August 1990. Further particulars and Conditions of Appointment may be obtained from the undersigned to whom applications must be addressed: A.W. Hayward, Registrar, University of Canterbury, Private Bag, Christchurch, New Zealand. The University has a policy of equality of opportunity in employment.

Institut national de la recherche scientifique, INRS—Telecommunications, Montreal, Canada, invites applications at all levels for tenure-track positions in image communications and software for telecommunications. Specific areas of interest are fast algorithms, architectures and signal processing for image communication, and software and discrete event system modelling for telecommunications. The successful candidate will need to develop a strong research base as well as take part in graduate teaching. A PhD in Electrical Engineering or Computer Science is required for all positions. The working language of the Institute is French. INRS—Telecommunications is a Centre for research and graduate studies, affiliated with the University du Quebec and co-located with the research laboratories of Bell-Northern Research in Montreal. Excellent, up-to-date facilities for research are available. Applications may be sent to: Dr. R. deB. Johnston, Director, INRS—Telecommunications, 3 Place du Commerce, Ile-des-Soeurs, Quebec H3E 1H6, Canada. Tel.: (514) 765-7846. Fax: (514) 765-8785. All qualified candidates are encouraged to apply but, in accordance with Canadian Immigration laws, preference will be given to Canadian citizens and landed immigrants.

The Department of Electrical and Computer Engineering at Oregon State University invites applicants for a tenure-track faculty position at Assistant/ Associate Professor level in computer engineering beginning Winter 1991. The specific area of interest is parallel computer architectures. Candidates must have an earned doctorate in electrical/computer engineering, the ability to teach effectively, and a commitment to develop a significant sponsored research effort. With a faculty of 27, the department enrolls 600 undergraduate and 80 MS/PhD students. Regional corporations such as Hewlett-Packard, INTEL, MENTOR, NCUBE, Tektronix, and others support computer engineering research in the Department. The Department recently expanded its facilities with the addition of a new building. Located in the Willamette Valley 80 miles south of Portland, OSU and the city of Corvallis offer unsurpassed livability in a quality environment. Applications must include a comprehensive resume, a list of three professional references, and a letter of interest. Address applications and inquiries to Dr. Patrick M. Lenders, Chair, ECE Department Faculty Search Committee, Department of Electrical and Computer Engineering, Oregon State University, Corvallis, OR 97331-3211. Review of applicants will begin October 1, 1990 and continue until the position is filled. Oregon State University is an Affirmative Action/ Equal Opportunity Employer and complies with Section 504 of the rehabilitation Act of 1973. OSU has a policy of being responsive to the needs of dual career couples.

Research Associate: Ph.D. in Materials Science plus 3 years training in Advanced Materials Science R&D required. Must be experienced in assembly, maintenance, and operation of deposition systems, vacuum equipment, and vacuum deposition procedures. Must also have fundamental and theoretical knowledge of solid-state semiconductor physics and formation, processing, and analysis of advanced electric materials; experience with SEM, DSC, TGA, Auger, adhesion testing, profilometer, photolithography, and mask aligners; experience with etching, evaporation, and sputtering techniques and equipment; and working knowledge of Macintosh, IBM, and PC-compatibles. R&D of deposition, characterization, and application of polycrystalline diamond and diamond-like carbon with specific emphasis on mircoelectronics, high power substrates, and high energy storage. Responsible for assembly and operation of ASTeX's system to grow diamond films and study growth kinetics. Will also study feasibility of deposition various substrates; effects of growth process upon thermal, mechanical, chemical, dielectric, and optical properties. Will write technical and scientific progress reports, refereed papers, and thin film processes, technologies, and equipment. 7:45 a.m. to 4:45 p.m., 40+ hours per week, $25,000 per year. Apply to Connie W. Spates, Alabama State Employment Service, P.O. Box 1072, 741 East Glenn Avenue,

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Microelectronics Engineers. The School of Microelectronic Engineering at Griffith University (Brisbane, Australia) seeks to appoint two new lecturers. This is part of the continuing expansion of the School of Microelectronic Engineering of the Division of Science and Technology. The School provides [redacted] coordinated coverage of integrated electronics with applications in the areas of integrated analogue and digital electronics, solid state physics, communications, computing, digital systems and control systems. Applications [redacted] sought from people currently working in academic institutions, private industry and government laboratories or recent doctoral graduates who have expertise in any of the areas indicated. It is anticipated that applicants will have a higher degree and an interest in working in an active teaching and research environment. Opportunities to initiate new research projects are available in addition to working with [redacted] number of existing research teams. Specific teaching experience required includes integrated electronic circuit design and applications in communications (hardware and software), digital circuits and systems, intelligent systems, microelectronics design and technology. The appointees will be expected to commence duties not later than January 1991. It is expected that the appointments will be made in the lecturer salary range, \$A32,197 to \$A41,841. Benefits include superannuation and assistance with removal expenses for appointees from outside Brisbane. The University is interested in increasing the proportion of women in positions of this kind. Accordingly, applications from both men and women are encouraged. There are some child care facilities on the campus which provide full-time and after-school care, but there is no guarantee of [redacted] place in the facilities. Further details may be obtained from Mr. J.R. Walden, Divisional Administrator, Division of Science and Technology, Nathan (Brisbane) 4111, Australia, to whom applications (including curriculum vitae and names and addresses of three referees) should be sent by 14 September, 1990. (FAX number (07) 875-7656). Griffith University is [redacted] equal opportunity employer.

Staff Position. Sr. Development Engineer/Chief of Electronics Staff—University of California, Davis, Physics Department. \$3625-5441. The Physics Department of the University of California at Davis is seeking [redacted] exceptionally experienced electronic engineer to head its electronics staff for advanced design and operation of instrumentation of physics research and teaching programs. This is [redacted] career University of California position in [redacted] college town with affordable housing. The engineer will work closely with faculty, research staff and graduate students. The experimental research programs in the Department are active and diversified. The candidate must have extensive experience in physics research laboratories and expertise in all the following areas: 1. Design and fabrication of major circuits with digital components: (a) TTL, (b) ECL, (K) Advanced CMOS, (d) pals and their programming. 2. Operating knowledge and component design and fabrication for large data acquisition system interfaced with bus used in physics experiments: (a) CAMAC, (b) FASTBUS, and (c) VME. 3. Design, fabrication, and operation of circuitry used in condensed matter experiments: (a) Operational amplifier circuitry, (b) Lock-in detector circuitry, (c) Radio-frequency circuits up to 1 GHz, (d) Pulsed NMR circuitry. 4. Design, fabrication, and operation of stable and very low noise systems: (a) Preamplifiers, (b) Charge sensitive Pre-amps, (c) Shaping amplifiers. 5. Design, fabrication, and operation of high speed analog and digital circuitry and knowledge of nuclear instrumentation; e.g. Photo-multipliers, gasious and solid state detectors. 6. Experience in using modern design tools: (a) Computer-Aided Design, (b) Analog circuitry simulation e.g. SPICE, (c) Digital circuitry simulation, e.g. PCAD. Apply to U.C.D. Employment Office, TB-122, Davis, CA 95616-8677 for Job Number 0516 open until filled but not later than July 31, 1990. Applications and resumes should include [redacted] statement detailing experience in each of the sub-categories above, and the names and addresses of two active research physical scientists for reference. For application material call (916) 752-0531, M-F, between 10:00a.m. and 2:00p.m. Equal Opportunity Employer/Affirmative Action Plan F/M/H.

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Electronics Engineer for firm in NE Ohio. To participate in the design and development of onsite/ remote Cardiac Rehabilitation Patient Monitoring Systems and microprocessor/electronically controlled exercise equipment. This involves developing machine and high level language programs; designing and developing voice/data integration analog/digital circuitry for fiber optic communication to prevent electromagnetic interference and to achieve total electrical isolation; designing and modifying radio frequency electro-cardigram transmission analog/digital circuitry; designing and developing the microprocessor and electronic controls for the Eddy Current Loading device necessary for the remotely controlled exercise equipment; and preparing the overall systems documentation for FDA and FCC approval. Must have M.S. in Electrical Engineering and academic program must have included one graduate level course each in: Computer Architecture, Expert Systems, Microprocessor Interfacing, Digital Signal Processing, Digital Data Acquisition, Advanced Microcomputer Systems, and Computer Communication Networks. Must have 2 years in electrical engineering and experience must have been in designing and developing microprocessor-controlled instrumentation. 40 hrs/wk, 8am-5pm, \$37,500/yr. Must have proof of legal authority to work permanently in U.S. Send resume in duplicate and course transcript (NO CALLS) to J. Davies, JO#1084555, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216.

North Central Illinois company has position for Engineering Manager, Frequency Control Division, Quartz Crystal Products. Duties: Directs and manages all engineering activities of Frequency Control Division to design, process, manufacture and test precision high frequency electronic quartz crystal resonators (1 MHz up to 500 MHz); reviews all advanced designs to establish concepts, determine feasibility and manufacturability; reviews all new program "request for quotations" from customers to provide appropriate design and process direction; trains all engineering personnel in advanced design and process concepts; provides applications engineering information to sales and marketing staff (for customer support capabilities); trains quartz crystal marketing staff in advanced product capabilities; provides research and development suggestions to top management; confers with management, production and marketing staff to determine engineering feasibility, cost effectiveness, and customer demand of new and existing products; assists in developing forecasts of operating costs of division; [redacted] oversees the establishment of new research and development projects. Will direct and coordinate the research, design, development and training of technical staff of ten, six possessing technical undergraduate and/ or graduate degrees, one possessing [redacted] two year applied science degree and three non-degreed technicians. Responsible for directing the specifications for state-of-the-art manufacturing and test equipment. Basic 40 hours per week, 8:00 a.m. to 5:00 p.m.; \$3,917 per month, overtime pay not applicable. Minimum education, training and experience: 4 years college graduate with B.S. degree in Electrical Engineering/or Electronic Engineering/or Electrical Engineering Technology/ or Physics; or equivalent two year associate's degree in Electronics/Engineering Technology and four years of progressive experience in engineering design, testing and manufacture of electronic components resulting in application of products for commercial uses; or eight years of progressive experience in engineering, design, testing and manufacture of electronic components resultin in application of products for commercial uses. Two years experience [redacted] Engineering Manager or six years experience [redacted] Design Engineer, (Quartz Resonators). Also research, design, testing, manufacture and/ or processing experience in field of high frequency quartz crystals resonators. Send resume to: Illinois Dept. of Employment Security, 401 State St.—3 South, Chi., IL 60605, Attention: Len Boksa, Reference #1436-B, An Employer Paid Ad.

Electrical Engineer/ Senior Project Manager-Cordless Telephones. We are seeking an EE who can apply 5 years plus experience to all phases of the design and development of cordless telephones. The right candidate will be [redacted] innovative leader who can motivate people and mobilize resources to carry out this project. Send resume to: Esquire Radio & Electronics, Inc., 4100 First Avenue, Brooklyn, New York, 11232.

Engineer, Staff: Design & test software; develop s/w for Fault-Tolerant Operating Systems; consult re. special s/w techniques such as Decentralized control of Error Recovery & Real-Time Error Recovery, on requests from far-Eastern clients including Korea, Japan, & Taiwan. \$4500/ mo. PhD in Comp. Sci. & 3 yrs. research exp. req'd. Knowledge of FT techniques such as Conversation & Distributed Execution of Recovery Blocks. Applied knowledge & exp. in Concurrent Language-Based Operating Systems. Send ad & resume to: Job #EG 14966, P.O. Box 9560, Sacramento, CA 95823-0560, no later than July 31, 1990.

Engineer (Senior advisory): Req. Ph.D. ECE and 3 yrs. exp. or research in thin film magnetic recording media, including sputtering deposition techniques, ferromagnetic resonance spectroscopy (FMR), vibrating sample magnetometry (VSM) and torque magnetometry (TM), x-ray diffractometry, profilometry and stress measurement, correlation between microstructure and magnetic properties, effects of vacuum [redacted] air annealing on intergranular coupling & computer simulation & data analysis. To design new types of thin film recording media for high density data storage. To deposit and characterize magnetic thin films by using sputtering, FMR, VSM, TM, x-ray diffractometry and profilometry, and to study the correlation between the microstructure and the magnetic properties, and the effects of vacuum and air annealing on inter-granular coupling. \$50K/yr. Job site/interview: Fremont, CA. Send this ad and your resume to job [redacted] CP13888, P.O. Box 9560, Sacramento, CA 95823-0560 no later than August 2, 1990.

Applications Engineer to maintain customer accounts, engineering tracking changes, purchase orders & overall customer relations of automotive safety controls including air bags, on a daily basis; review Chrysler specifications & advise Chrysler engineering regarding engineering/manufacturing requirements to meet time & budgetary constraints; determine technical requirements for automotive client's safety applications in terms of performance, metallurgical properties, product design, assembly & production; generate internal management reports of production status, forecasts & current industry trends; act [redacted] liaison to develop automotive safety controls suited to client applications; liaise with engineering & purchasing departments relative to preparation of quotes, technical service & training. Bachelor's degree in Electrical Engineering Technology required as well [redacted] 6 years experience in job offered or 6 years experience as Technical Sales Engineer and/ or Field Service Representative and/ or Sales Representative. Experience must have involved participation in design [redacted] manufacture of prototypes of electronic trailer tow module & rear deck lid closure modules. 40 hours, 9:00am to 5:00pm, \$41,532/year. Send resume to 7310 Woodward Ave., Room 415, Detroit, MI 48202, Ref. #26390. Employer paid ad.

Central Electronics Engineering Research Institute Pilani (Rajasthan) 333031, India. Director, Central Electronics Engineering Research Institute, Pilani (Rajasthan) 333103, India invites applications from Indian nationals, Ph.D./M.S. with specialization/professional experience of a few years in [redacted] branch of microelectronis or industrial process control or power electronics. Send detailed resume and names and address of three professional references to the above address on or before August 15, 1990.

Scientific Programmer—Position available for a person to conduct research into computer simulation technology and power systems engineering techniques. Will incorporate results into the development of applications that emulate electric power networks and train utility power dispatchers. Position requires a PhD in

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Electrical Engineering, with an emphasis on large scale power systems operation and control, electric power network transmission modeling and simulation, and at least two years experience in the development of utility power systems dispatcher simulators using FORTRAN. Must be a U.S. Citizen or permanent resident. Salary $4250/month. Send resume to: S. Springmeyer, #0-114, Minnesota Department of Jobs and Training, 390 N. Robert St., Room 124, St. Paul, MN 55101. Affirmative Action Employer.

Senior Design Engineer. Responsible for the design and development of frequency hopping and standard radio communication receivers integrated in communications service monitors. Design Duties: Conceptual design—analyze and evaluate the performance of optional block diagrams, select the best cost effective one. Implementation—design the receivers' RF hardware (within 0.1MHz to 1300MHz), such as filters, tuners, IF amplifiers and modulation detectors. Integration—integrate receiver modules in the final equipment. Production support—prepare required documentation for receivers mass production, provide continuous technical support. Minimum requirements: BSEE, and at least five years of hands-on engineering experience in the design of radio communication receiver products. Experience must include at least one frequency hopping radio communication receiver product design, designed to be manufactured in [redacted] production line, including: conceptual design, implementation, and integration (described in the design duties). Conditions: 40 Hours/Week 8:00 a.m. to 5:00 p.m. $40,000/year. Job site: Wichita, Kansas. Please send resume to Wichita Employment and Training Office 402 E. 2nd Wichita, Kansas 67202, phone-316-266-8600. Refer to Job Order No. KS 3301099. Must have proof of legal authority to work in the U.S. An equal opportunity/affirmative action employer.

Scientific Programmer—Position available for a person to research and design mathematical algorithms for computer systems that monitor and control the transmission of electric power, primarily in the [redacted] of large-scale power systems voltage stability assessment. Will integrate resulting computer program into a large, multi-main frame computer system. Must have [redacted] doctoral level degree in electrical engineering, with research in large-scale electric utility power systems voltage stability assessment mathematical algorithms. Must have taken an undergraduate level course in Fortran for the development of programs on computers that utilize either the NOS (Network Operating System) or NOS/VE (Virtual Environment) operating system, for graduate level courses in computer program design and techniques and thesis work in power systems analysis. Must be a U.S. citizen or permanent resident. Salary $3750/month. Send resume to: S. Springmeyer #0-137, Minnesota Department of Jobs & Training, 390 N. Robert St. Room 124, St. Paul, MN 55101. An Affirmative Action Employer.

3 Positions—Senior Engineer: Design/test elec. circts. of comm electronic power converters & power systems. Apply elec. principles, use computer design tools, survey commercially available components, design suitable software. Develop product applications: commercial, industrial, medical, military, scientific. Power electronic devices rated over 10 kw/use series resonant conversion techniques. Supervise technicians/programmers. MSEE or equiv req Min 4 yrs job exp or grad work since BS or equiv. 2 of the 4 yrs to incld exp w/power sys & power electronic devices rated over 10 kw using series resonant conversion techniques. 40 hrs/wk, 8-5, $40K/yr Resume to Emp. Div., Attn: Job No. 2418798, 875 Union St. NE, #201, Salem. OR 97311.

Automation/Robotics. R&D/D&D/Integration. Nationwide Recruitment & Placement. Bill Saur. Telos Consulting Services 916/447-8004, 106 K St., Sacramento CA 95814.

Senior Software Product Manager/Clinical Applications Scientist: Dynamic Digital Displays is currently seeking a Senior Software Project Manager and [redacted] Clinical Applications Scientist to assume leadership roles in the development of medical imaging software. A rapidly growing medical imaging firm, Dynamic Digital Displays manufactures high performance interactive, graphics/imaging workstations capable of 2-D, 3-D, 4-D and multiplanar image reconstructions at real time speeds. Our current top to the line platform, the VoxelScope II, offers powerful volume visualization tools used in diagnosis and surgery planning from CT and MR data sets. The Senior Software Project Manager will assume the responsibilities of leading a team of innovative software engineers in product development. Candidates interested in this position should have extensive experience in software engineering and project management. Previous experience in medical imaging, computer graphics and image processing is also highly desirable. The Clinical Applications Scientist will lead an experienced project team in the development of medical applications software for our platform. Interested candidates should have a PhD degree in [redacted] Computer Science, Electrical or Biomedical Engineering, [redacted] strong medical imaging background and the ability to interact with clinicians in order to define project goals. Dynamic Digital Displays is an Equal Opportunity Employer located in the suburbs of Philadelphia and offers competitive salaries and benefits. Interested candidates should send resumes and curriculum vitae to: Mr. David Talton, President, Dynamic Digital Displays Inc., St. Davids Center, 130 Radnor-Chester Rd., Suite 100, St. Davids, PA 19087. (Phone 215-975-0975).

Executive Technical Director wanted by a SW Ohio business to direct and coordinate activities concerned with the installation and service of new and existing product systems through delegated subordinates; confer with project personnel to provide technical advice and to assist in solving technical problems; review, prepare and negotiate complex technical and commercial proposals; conduct component level maintenance training courses at customer presmises personally and through delegated subordinates; develop and implement methods and preparation of records of expenditures, progress reports and staff conferences in order to inform management of the current status of each project; supervise [redacted] individuals and; must be able to travel on an international basis approximately 6 times per year for periods of up to two weeks at [redacted] time. Four years college required with the major field of study being either electronics or electrical engineering. No exp. required in above duties but applicants will qualify with 3 years [redacted] a Systems Engineer involved with optical gauging control. Must have at least 2 years experience with solid state CCD (charge coupled device), infra-red detectors and the application of such to the measurement of hot mill steel. (The two year experience may be gained during the 3 years as a System Engineer.) 40 hrs/wk. 8:30 a.m.—5:30 p.m. $50,000 year. Must have proof of legal authority to work permanently in U.S. Send resume in duplicate (NO CALLS) to L. Eggleston, JO# 1244830, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216.

Electronics Science and Technology Division— Electrical Engineer GS-12, $35,825 to $46,571 (salary dependent upon qualifications). The Electronics Science and Technology Division (ESTD), Naval Research Laboratory, invites applications for the position of Research Electrical Engineer in the Ion Implantation and Epitaxial Surfaces Section of the Surface Physics Branch. This Section carries out research into the physics and chemistry of III-V Molecular Beam Epitaxy and Ion Implantation in an effort to enhance the application of these processes to the III-V electronic and optoelectronic device and IC technologies. The Section is seeking a candidate who has at minimum [redacted] Ph.D. in Electrical Engineering (or equivalent) with research experience in the growth of III-Vs and related compounds by molecular beam epitaxy. In particular, the candidate should have experience in the MBE techniques for atomic layer epitaxy and should have direct experience in the growth of materials for optoelectronic and electronic device applications. Additional expertise in transport and optical measurements is desirable. In particular the successful candidate should be able to correlate measured transport and optical properties with MBE growth parameters and be able to optimize the latter for a variety of device and IC applications. To apply: Submit [redacted] Application for Federal Employment (SF-171) or detailed resume by 31 July 1990 to: Naval Research Laboratory, Civilian Personnel Division, Attn: 68-084-89, 4555 Overlook Avenue, S.W., Washington, DC 20375-5000. Phone: (202) 767-3030. An Equal Opportunity Employer, U.S. Citizenship required.

Senior System Engineer. For Roanoke, Va. area emp. Resp. for design of cont. systems for steel industry hot rolling mills incl. def. of sys. funcs. & function dist. among diff. units of equip. Def. of system signals & system data flow; design coordination; define & implement integrated system tests; system installation on site. Job includes worldwide assigns. of undetermined & varying duration. Must have M.S. or equiv. in Elec. Eng. w/6 yrs. wrk. exp. in metals industry automation, particularly reversing plate mills, hot strip mills, cold rolling mills, reheat furnace control & blast furnace control. Proficient w/ Directomatic II & Directomatic Plus Equip., software langs. PAL Assembly, Fortran, Pascal, ASM 80 & Assembly. 40 hrs./wk. Hrs. 8:00-4:45, $47,500/yr. No OT. To apply: Mail or hand carry res. w/copy of ad attached. to: VEC, Dept. 3008, 1202 Franklin Rd., Roanoke, Va. 24002-0061, JO #VA9032113. EEOE.

Research Engineer. Resp. for conducting research and development of semiconductor epitaxial materials growth by metalorganic chemical vapor deposition. Reqs. a Ph.D. in E.E. or Materials Science. Also reqs. doctoral research in particular epitaxial growth for development of opto-electronic devices; reqs. background in optical absorption and infrared reflection spectroscopy; photoluminescence spectroscopy; and electron microprobe spectroscopy; knowledge of semiconductor device theory. Salary: $48,000/yr. Interview/job site: Palo Alto, Ca. Send this ad & your resume to Job #TC 14303, P.O. Box 9560, Sacramento, CA 95823-0560 not later than July 30, 1990.

Chief Electrical Engineer/Inspector to design and perform on-site inspection of major construction projects. Direct, supervise, and monitor performance of engineer staff assistants. Requires B.S. Electrical Engineering or equivalent education and 8 years experience in design and field inspection of heavy industrial electro mechanical power systems. Position in Seattle area. $3847/month. Send resume by 1 August, 1990 to: Employment Security Dept.: E.S. Division Attn: Job No. 203355, Olympia, Wa. 98504.

Biomedical Staff Engineer/Scientist for state-of-the-art medical consulting, and new product definition and design. Education: PhD Biomedical Engineering, with MS in EE. Requirements: 7+ years of experience in design, application, and clinical evaluation of electronic medical equipment; with special emphasis on diagnostic analysis of cardiovascular system. Frequent overseas travel required. Capability to fluently communicate in Russian. Salary $48,600 per year, depending on experience. Place of employment and interviews: Menlo Park, CA. Send this ad and resume or letter stating qualifications to Job #NOF788, P.O. Box 9560, Sacramento, CA 95823-0560 not later than July 26, 1990.

Senior Development Engineer for mftr. in NE Ohio—40 HR/WK; O.T. as req. 9AM-5PM Sal. $40,680 per yr; Education required: Bachelor's Degree in Electronic Engineering. Of the 4 yrs of college required, must have completed a minimum of 3 undergraduate level courses in electronic circuits; minimum of 2 undergraduate level courses in electrical engineering; a minimum of 3 undergraduate courses in mathematics & at least 1 undergraduate course in physics. Must be able to travel within the U.S. at least 5% of the time. Exp. required: 5 yrs in the job offered as a Senior Development Engineer or [redacted] yrs as an Electrical Engineer. Responsibilities: designing & implementing hardware modules for microcomputer-based distributed control system; programming & designing [redacted] wide variety of systems including analog & digital design through command of assembly languages. Design includes working with Multibus, interface, interrupt controller, DC-DC converter, serial channels, RAM, Eprona, Lithium battery backup, counter/timer, & numerous PALs. Analog design includes signal conditioning, isolation techniques, power supplies & linear control theory. Digital design includes 8 & 16 bit micro processor memories, peripheral devices & programmable logic devices including TTL & MOS devices. Additional responsibilities include working with industrial programmable control systems, networking,

multi-processing & programming software from the perspective of design & application; coordinating & supervising all phases of development of each project (including manufacturing introduction); & supervising [illegible] directing an 8-man team of engineers & staff assistants in development & engineering projects. Must have proof of legal authority to work in U.S. Send resume in duplicate (no calls) to J. Davies, JO#1084548, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, OH 43216.

Senior Design Engineer for [illegible] small high tech company that specializes in high speed digital signal processing (DSP) applied to high performance demanding factory automation. DUTIES: Design and development of microprocessor based control system for computerized factory automation. Develop software on high speed digital signal processor. Design software for control algorithms. Design software for hardware and microprocessor interface. Design software for computer and computer communications. Theoretical analysis of system dynamics and system performance. Numerical analysis of control algorithms. Design hardware for high speed microprocessor based and digital signal processor based controller. System analysis, control design synthesis and understanding the physical relationship between the elements of electromechanical systems. MINIMUM REQUIREMENTS: Master of Science in Electrical Engineering; nine months experience as a Research Assistant including the following concurrent specific experience: (1) nine months experience in theoretical and practical controller design or control algorithm design; and (2) nine months experience using control simulation tools, including PC-MATLAB. The following graduate coursework is required for this position as part of the MSEE: (1) Digital Filter Signal & Theory, (2) Systems Analysis, (3) Kalman Filtering and Applications, (4) Modeling & Simulation of Dynamic Systems, (5) Linear Optimal Control, (6) Computer Aided Design, (7) Advanced Research is DSP (TMS320C25 Digital Signal Processor) Hardware Interface. SALARY: $42,000 per year. Fulltime. Send resume to Lawrence Cheetham #0-89, Minnesota Department of Jobs and Training, Room 124, [illegible] North Robert Street, St. Paul, Minnesota 55101.

Manufacturer of computers in Denver, Colorado seeks Network Design Engineer to apply OSI model to the design and development of network architecture for PC server-based and terminal-based LANs. Use Fiber Distributed Data Interface (FDDI) to provide high-performance backbone network. Engage in multi-vendor networks planning, design, installation, and service and maintenance. Design and test RF emissions and conduction radiation on devices to assure compliance with FCC regulations. Supervise network service team. Requires B.S. in Electronics Engineering and two years testing and design of RF interference on 386/486 PCs and mainframe computers and experience in FDDI LANS applications. (Experience may be gained concurrently.) $30,000/year; 8:30-5:30, M-F. Respond by resume to James Shimada, Colorado Department of Labor & Employment, Division of Employment & Training, 600 Grant St., Suite 900, Denver, CO 80203, and refer to Job Order No. CO3193398.

Controls Designer for electronic dry kiln control systems. Applicant must be able to design and customize dry kiln control systems which measure and regulate the drying process for lumber, veneer, and wood chips. Design and draft the hardware and software for electronic dry kiln control devices. Develop/design the circuitry for the P.C. boards. Write the microprocessor programs for these kiln-drying systems to ensure the wood drys at the optimum rate and temperature. Consult with others, both in the U.S. and in Germany, regarding these designs. Must be able to speak and read German and have knowledge of how to measure the humidity of lumber. B.S.E.E. in Electrical Engineering and 1 year experience is required. 40 hrs wk; $2,360 mo. Apply: Employment Division, Attn: Job Order #2418634, 875 Union St. NE, Rm 201, Salem, OR 97311.

Electrical Instrumentation Engineer. Laying out, testing, and evaluation of new circuits as improvements to Mossbauer Spectrometer and radiation detection system, programming and interfacing the PC with instruments, programming to improve the curve fitting, some machine-shop work for improving transducer, utilizing laser interferometer and optical techniques for velocity calibration, designing temperature control unit for low temperature cryogenics and high temperature furnace. Must have a Master's Degree in Electrical or Instrumentation Engineering or all requirements completed. In addition, coursework must have included the following: 15 credit hours in nuclear instrumentation and electronics, 21 credit hours in programming and mathematical analysis, 15 credit hours in microcomputer and microprocessor and [illegible] thesis or one year research on fast radiation detection system. Salary: $32,169.00 per year/ 40 hours per week. Apply at the Texas Employment Commission, Ft. Worth, Texas or send resume to Texas Employment Commission, TEC Building, Austin, Texas 78778, J.O. Number 5518168. Ad Paid by an Equal Employment Opportunity Employer.

Senior Research Engineer—Development of systems for analyzing electromagnetics using finite element analysis. Modeling of plasma discharges using finite element methods. Performing heat transfer analysis. Salary, $40,000 per year, basic, 40 hour week (8:30 a.m.—5:30 p.m.). Requirements, Eight years college with a Ph.D. Degree in Electrical Engineering; Master Degree in Physics; Doctoral Thesis in Plasma Physics is required. Send resume: MESC, 7310 Woodward Ave., Room 415 (Reference No. 41090) Detroit, MI 48202. Employer paid ad.

Chief Engineer (Engineering Services). A prominent Mid-Atlantic based engineering services company is seeking a chief engineer to support [illegible] division of 600, with direct responsibility for [illegible] group of 100. The ideal candidate will have an MSEE coupled with [illegible] significant amount of broad engineering management experience. Examples of current business [illegible] include C3 and avionics communications, modification engineering and test technology. This individual will be an integral part of the management team participating in strategic planning, implementation planning and business development. Excellent compensation and benefits package. Please send resume and salary history in strict confidence to: P.O. Box 70022-C, Washington, D.C. 20088.

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Global theme stressed at Brussels meeting

Among the dignitaries met by the IEEE Board of Directors at its recent meeting in Brussels were the U.S. Ambassador to the European Community (EC), EC headquarters officials, and officers of IEEE Region 8. In these sessions, the Board stressed the theme of the IEEE as a global association of professional EEs, transcending national borders and political interests.

The Board also received several briefings on the progress of the EC's member states toward forming a single market. At one, an EC official praised the IEEE's work in international standards such as Posix.

IEEE President-Elect Eric Sumner spoke at the joint meeting of the Board and the Region 8 Committee, predicting that at current growth rates of members in Regions 8–10, within a few decades, IEEE membership might be a third each from Europe, Asia, and North America [THE INSTITUTE, July, p. 1].

Board ponders dues increase

The expense of maintaining and improving members' services may require an increase in dues to balance the 1991 budget, the IEEE Board of Directors found at its recent meeting in Brussels. At the present dues level, the preliminary budget would require withdrawing $1.3 million from reserves, which have been declining since dues were last raised in 1988. To balance last year's budget, $2.2 million was taken from the reserves, and to keep reserve levels from falling too low, the Board voted to raise the minimum level from 25 to 35 percent of operating expenses. The actual level is currently at 50 percent.

The Board also approved plans to replace the IEEE's outdated data-processing system at a cost of $4 million, to be spread over several years, beginning in 1991. The new system will allow members around the world to access IEEE databases and to use electronic mail more effectively [THE INSTITUTE, July, p. 1].

The candidates and the issues

The restructuring of the IEEE's volunteer organization should be approached cautiously, agree the five candidates for 1991 IEEE President-Elect, but they disagree on such other issues as dues increases. The candidates are Edward C. Bertnolli, Merrill W. Buckley Jr., Theodore W. Hissey Jr., Edward A. Parrish, and Martha Sloan.

On volunteer restructuring, Bertnolli favors allowing the members to vote on the issue, Buckley warns against reducing the Educational Activities Board's effectiveness, and Hissey stresses that standards should be part of the overall IEEE rather than a sub-group within IEEE-U.S. Activities. Parrish believes that the new regional entities proposed under the reorganization would lack technical content, and Sloan feels that enough time has passed for members to comment on the idea and that it should be resolved soon.

When asked whether any recent IEEE actions or inactions now seemed inappropriate to them, Sloan said that slow delivery of IEEE publications was a problem, and Parrish cited the IEEE's reluctance to take risks and its slow implementation of services such as electronic mail. Hissey noted that the IEEE should have taken more action to increase international thinking and activities, Buckley thought that not consulting the membership on such issues as the proposed amending of the Code of Ethics was a mistake, and Bertnolli described the addition of the associate general manager level to the IEEE staff as an error [THE INSTITUTE, July, p. 1].

Members surveyed worldwide

The results of the first IEEE worldwide member opinion survey are in. Among the findings: 25 percent of non-U.S. members work in educational institutions as opposed to 8 percent of U.S. members, and the primary job activity of 53 percent of non-U.S. members and 46 percent of U.S. members is research and development.

The "typical" IEEE member is a male in his early forties with a master's degree. If he works in the United States, he probably earns about $56 000 (salary data was not obtained for non-U.S. members). He also has access to a personal computer—86 percent of U.S. members and 89 percent of non-U.S. members are using PCs.

For further results, see the August issue of THE INSTITUTE.

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